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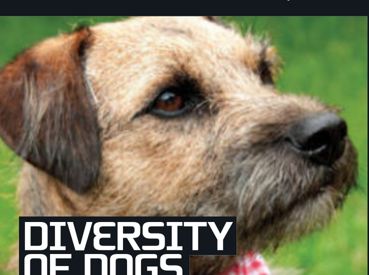
The upgrades that took Lewis Hamilton to the top



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Why do they come in so many shapes & sizes?

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+ LEARN ABOUT
- TUNNELS
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THE STORY OF HUMANS

How we crossed continents & conquered the planet

ISSUE 81

WELCOME

The magazine that feeds minds!

Page 22
Find out all about the new search for alien life

Are we alone? It's one of the biggest questions humans have wrestled with through the ages. But while this was once a dream, now it is a scientific quest. The Breakthrough Initiative is a pioneering new search for intelligent life in the cosmos, backed by Professor Stephen Hawking.

At the launch, he pondered what we might find: "A civilisation reading one of our messages could be billions of years ahead of us," he said. "If so, they will be vastly more powerful and may not see us as any more valuable than we see bacteria."

It's mind-blowing to think what's possible in an infinite universe, particularly since we believe life began spontaneously here on Earth. In this exciting issue, we not only explain the where, how and why behind this project, we also look at how far we have evolved as a species.

It's taken millions of years to get to this point, from producing the first stone tools and crossing continents, to building the enormous telescopes that are searching the skies for signs of life as you read this.

Here's to another year of exploring, learning and discovery!

Jodie

Jodie Tyley
Editor

Meet the team…

Duncan
Senior Art Editor
History's most gruesome inventions… erm, yep, there were some horrific ones. I'm not going back to the dentist any time soon!

Katy
Production Editor
If you overdid it on the mince pies and turkey this Christmas, head to page 40 to see how your insides coped and why you didn't go bang!

Phil
Staff Writer
The jetpack is finally here and could be used by the emergency services in the near future. Watch out for flying firefighters…

Jackie
Research Editor
Two and a half years. I've been suggesting a humans feature for *two and a half years*. It's finally happened! I can't quite believe it.

Briony
Assistant Designer
Just when you thought it was safe to go back in the water… our extreme oceans feature on page 54 will give you nine reasons not to.

Jo
Features Editor
After writing about stomach-churning inventions, I had to escape to Disneyland to forget all about choke pears and trepanning.

What's in store

Check out just a small selection of the questions answered in this issue of How It Works…

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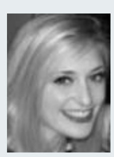
Meet the experts...

Laura Mears
Science expert Laura gives you a lesson in the fundamental building blocks of the universe – the elements. Did you know that we're all made of star dust? Find out more amazing facts like this on page 30.

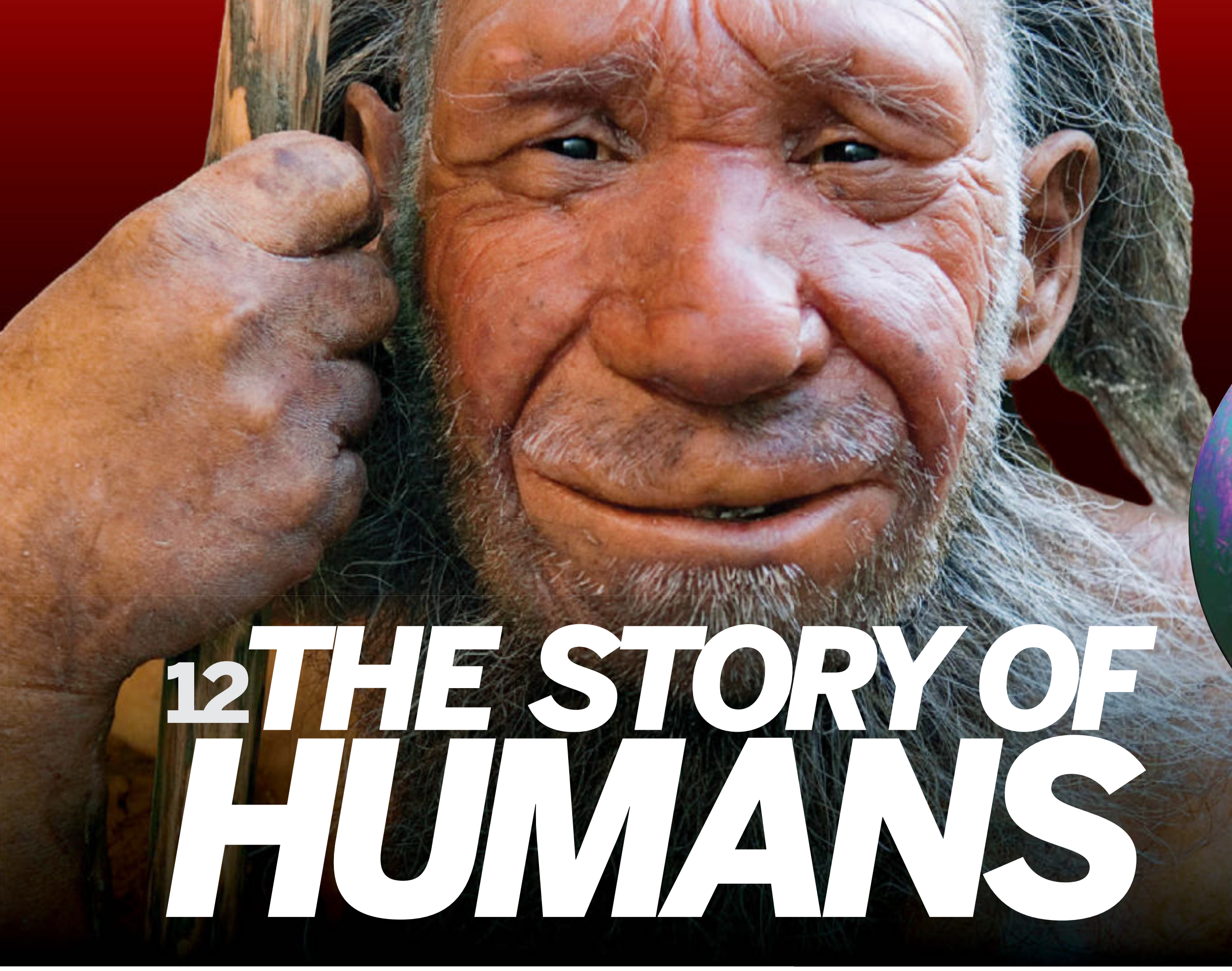
Gemma Lavender
This month, **All About Space** magazine's Gemma tells us how gravity wells keep the planets in orbit, and how we distinguish between stars and planets.



Ella Carter
In between taking her border collie Dexter to agility classes, Ella found time to explain how there have come to be so many breeds of dog (page 62), and give us a round up of the most extreme oceans on Earth.

Alexandra Cheung
Are snakes immune to their own venom? Why do women live longer than men? Alex answers some of your burning questions in this issue's Brain Dump.

Ceri Perkins
For this issue's ten-page special feature, Ceri journeys back in time to recount the incredible story of how humans evolved and conquered the planet.



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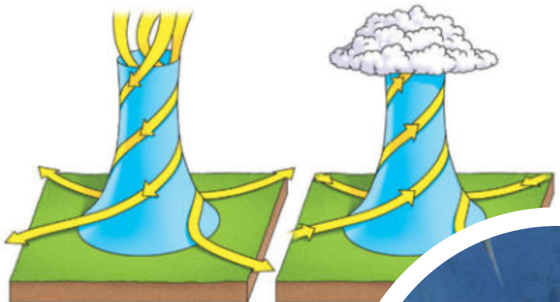

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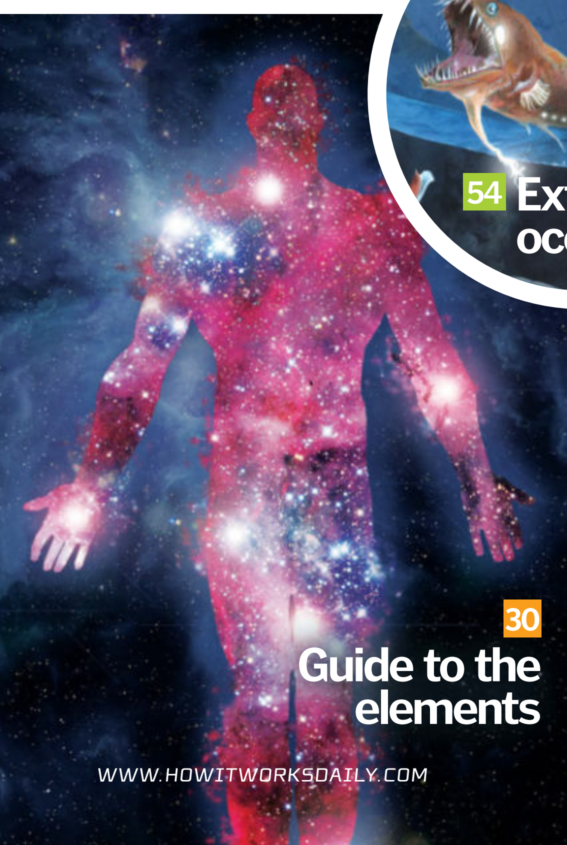

30 Guide to the elements

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The future of personal submarines

Explore the depths in the DeepFlight Dragon that anyone can pilot

Submarines are no longer reserved for naval warfare and fictional spies, as DeepFlight's new craft has made it easy for anyone to travel beneath the waves. The Dragon is a cross between a submarine and quadcopter, with six rotating thrusters that allow it to fly and hover underwater. The simple controls mean it operates just like a drone too, so anyone can pilot it without needing lengthy training.

The onboard DeepFlight Dive Manager monitors depth control, battery consumption and oxygen flow, so all you need to do is set the dive limit and fly. The lithium-iron-phosphate battery allows you to cruise for up to six hours between charges and operates quietly so you can sneak up on any marine wildlife. You and your passenger will be protected by the carbon composite chassis and pressurised cabin, and if you get into trouble, the sub's positive buoyancy will cause it to automatically float back to the surface.

You don't need much know-how to own a Dragon, but you do need deep pockets. The craft is available for an eye-watering £1 million ($1.5 million), but the good news is that it will fit perfectly on your yacht.

The two-seater sub can be controlled by either the front or back passenger

Simple controls make the Dragon very easy to operate with hardly any training

The specs

Dimensions: 5 x 1.9 x 1.1 metres

Weight: 1,800 kilograms

Operating depth: 120 metres

Cruising speed: 4 knots (7.4km/h)

Payload: 250 kilograms

The Dragon is the smallest and lightest personal submarine on the market

Pluto's Wright Mons ice volcano is about 160km wide and 4km high

Pluto goes psychedelic

NASA gives the dwarf planet a groovy paint job

While it would be cool if Pluto really was all the colours of the rainbow, this image has been falsely coloured by NASA scientists. Using a technique called principal component analysis, they adapted an image taken by the New Horizons spacecraft's Ralph/MVIC camera to highlight the subtle colour difference between Pluto's distinct regions. It shows the incredibly varied terrain of the dwarf planet, including a heart-shaped icy plain, deep craters and enormous mountains, as well as what NASA now believes to be ice volcanoes that tower four kilometres above the surface.

A false colour image of Pluto taken by the New Horizons spacecraft during its flyby

The real-life tractor beam

This Star Trek-style invention can move objects using sound

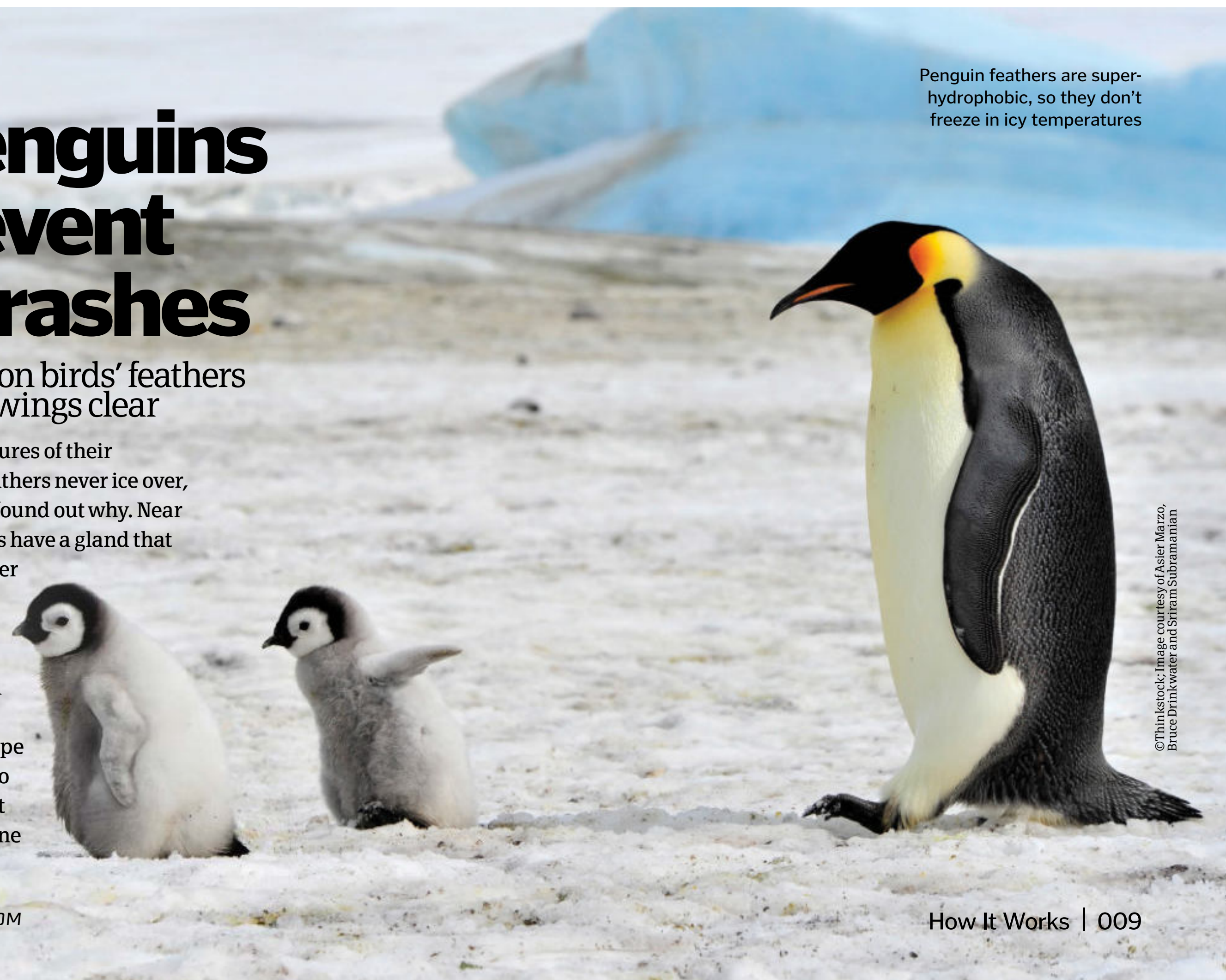
They have long been used in science fiction to pluck humans from the Earth, but now tractor beams have finally become a reality. Scientists at the University of Bristol have invented a device that can pick up and move objects using sound. Using an array of 64 miniature loudspeakers, the device produces high-pitch and high-intensity sound waves that create a force field around an object to keep it in place. By carefully controlling the output of the loudspeakers, the shape of the acoustic force field can then be manipulated to either move or rotate the object.

Sonic tractor beams could be used to transport drug capsules through living tissue

How penguins can prevent plane crashes

The natural de-icer on birds' feathers could keep aircraft wings clear

Despite the freezing temperatures of their Antarctic home, penguins' feathers never ice over, and new research has finally found out why. Near the base of their tail, penguins have a gland that secretes water-repellent oil over their bodies. This, combined with the tiny pores found on the surface of their feathers, means that water droplets roll straight off before they have time to freeze. Researchers hope these findings could be used to prevent ice forming on aircraft wings, a common cause of plane crashes in winter weather.



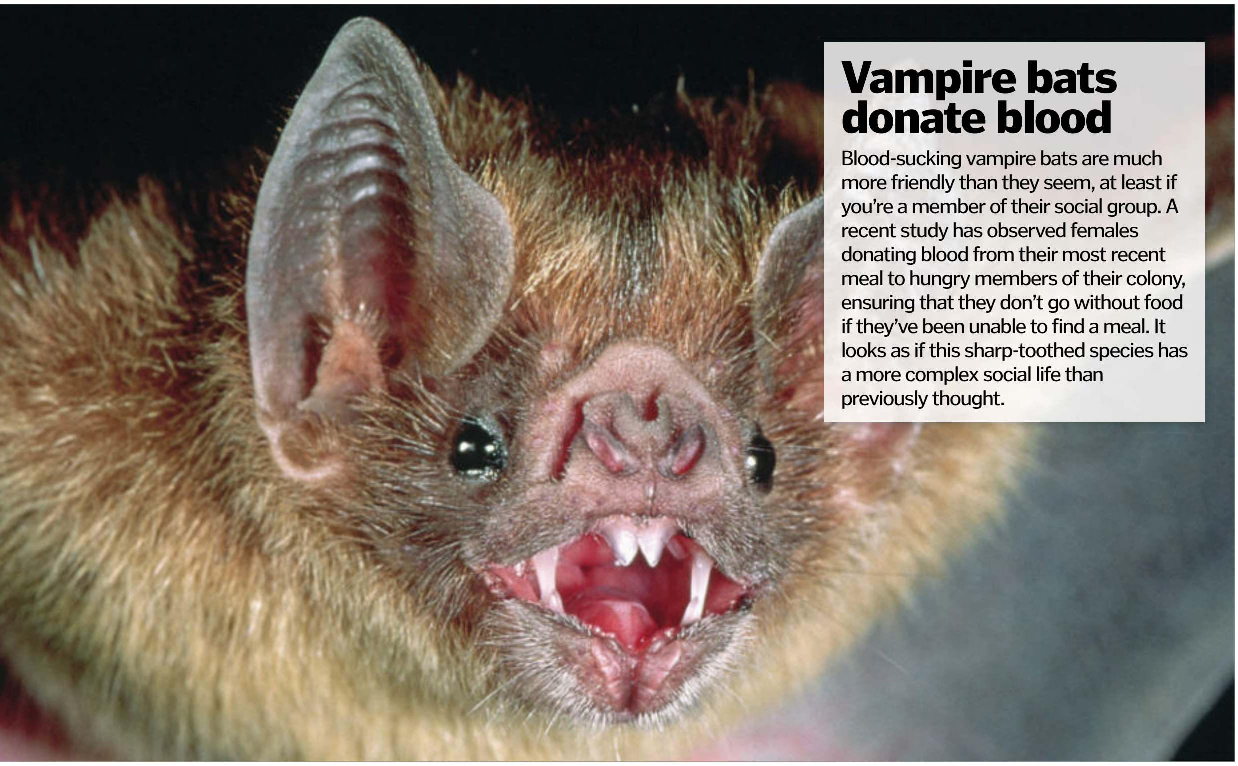
Penguin feathers are super-hydrophobic, so they don't freeze in icy temperatures

GLOBAL EYE

10 COOL THINGS WE LEARNED THIS MONTH

There's a device to scan food ingredients

A new gadget called Nima can examine a food sample for allergenic ingredients in minutes. It's composed of two parts: a disposable capsule that holds the sample, and a sensor that performs a chemical analysis of the food. Currently Nima only scans for gluten, but versions that detect peanuts, soy and dairy are being developed.



Vampire bats donate blood

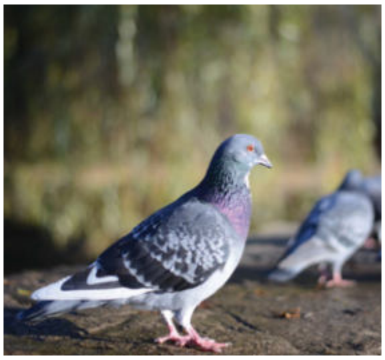
Blood-sucking vampire bats are much more friendly than they seem, at least if you're a member of their social group. A recent study has observed females donating blood from their most recent meal to hungry members of their colony, ensuring that they don't go without food if they've been unable to find a meal. It looks as if this sharp-toothed species has a more complex social life than previously thought.

A robot can ace exams

A robot developed by the National Institute of Informatics in Japan is smart enough to get into university. The Todai Robot achieved an above-average score on the standardised Japanese entrance exam, excelling in maths and history. There's room for improvement in physics, though.

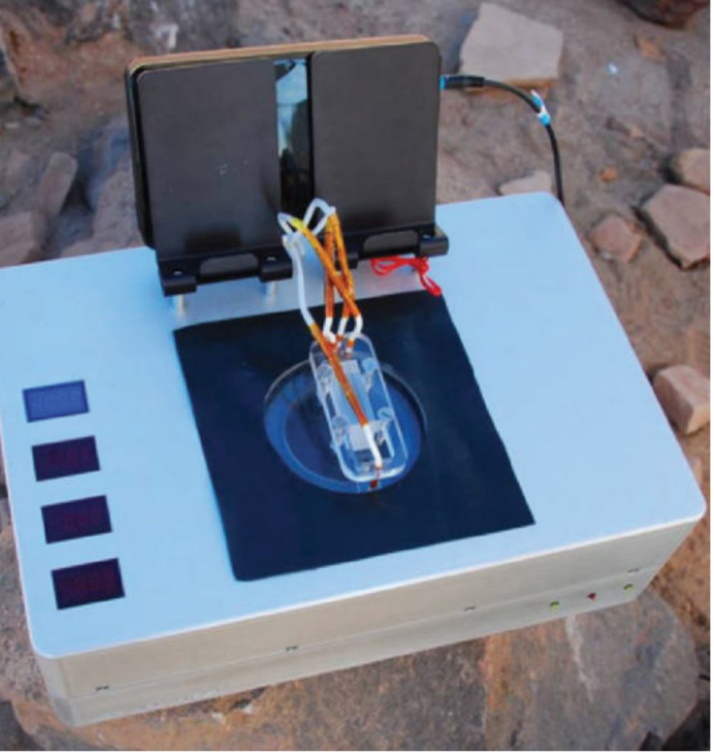
Some superbugs are now totally drug resistant

If all else fails, a group of drugs called polymyxins are the fail-safe antibiotics used by doctors to treat superbugs. However, scientists in China have identified bacteria that can fight through this last line of defence. Experts are worried that these particular strains will contaminate livestock and enter our food chain, which could lead to a health disaster.



Pigeon eyes have a magnetic protein compass

For a long time, scientists have been stumped trying to figure out the mechanism pigeons use to navigate, but new research may solve the mystery. Pigeon's eyes were found to contain special magnetic proteins, which align with the direction of a magnetic field, just like a compass needle. The research was led by a team from Peking University, who also found this magnetic protein – now named MagR – in butterflies and fruit flies.

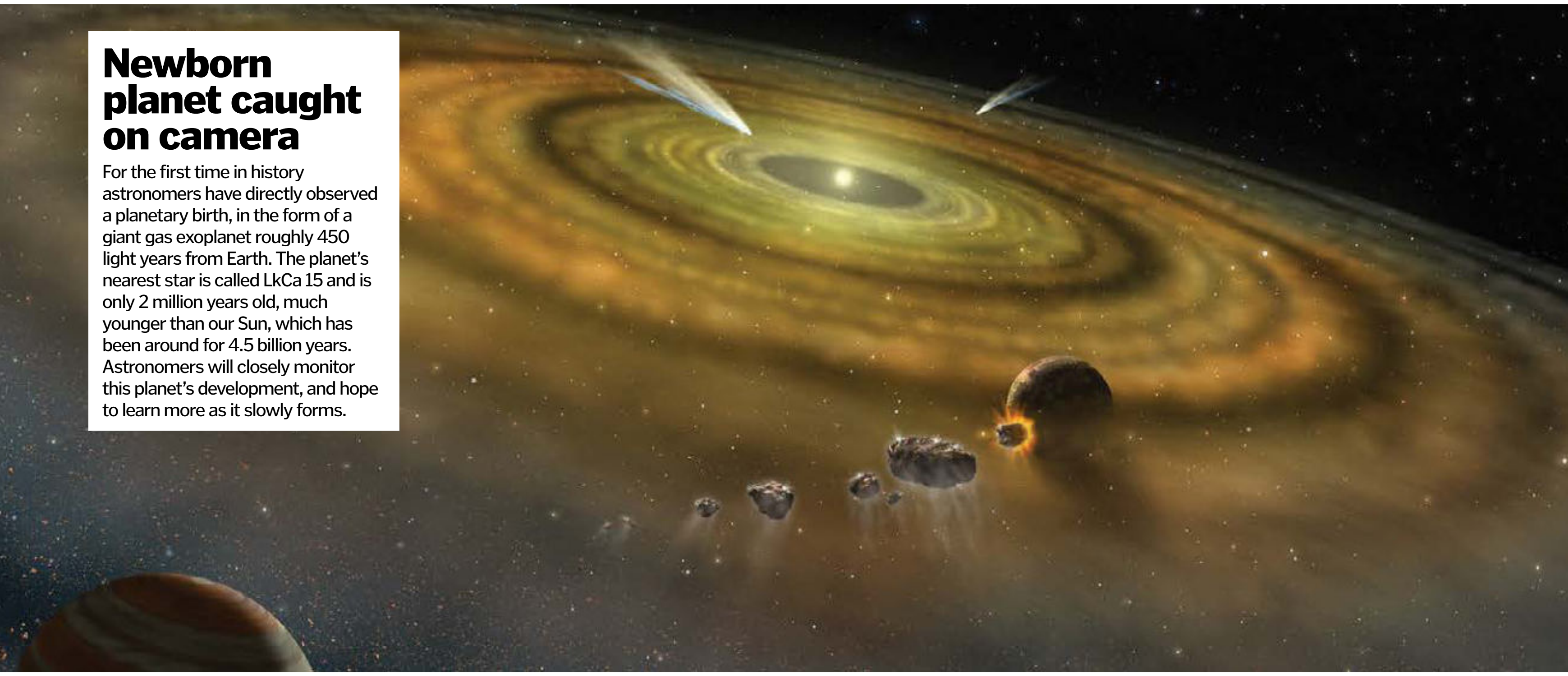


NASA has built its own 'tricorder'

In the search for alien life, NASA has designed the Chemical Laptop that acts as an off-planet laboratory. It will analyse objects in space for both amino acids and fatty acids – compounds that could indicate the presence of extraterrestrial life. Unlike Star Trek's 'tricorder' that could scan anything alien and identify it, NASA's creation mixes the sample with water and heats it to over 100 degrees Celsius before examining it.

You can get paid to walk

Bitwalking is the new digital currency from inventors Nissan Bahar and Franky Imbesi. Users can earn one Bitwalking dollar (BW$) for every 10,000 steps, and will be able to trade these in for cash or spend them online. Head to **www.bitwalking.com** to sign up.



Newborn planet caught on camera

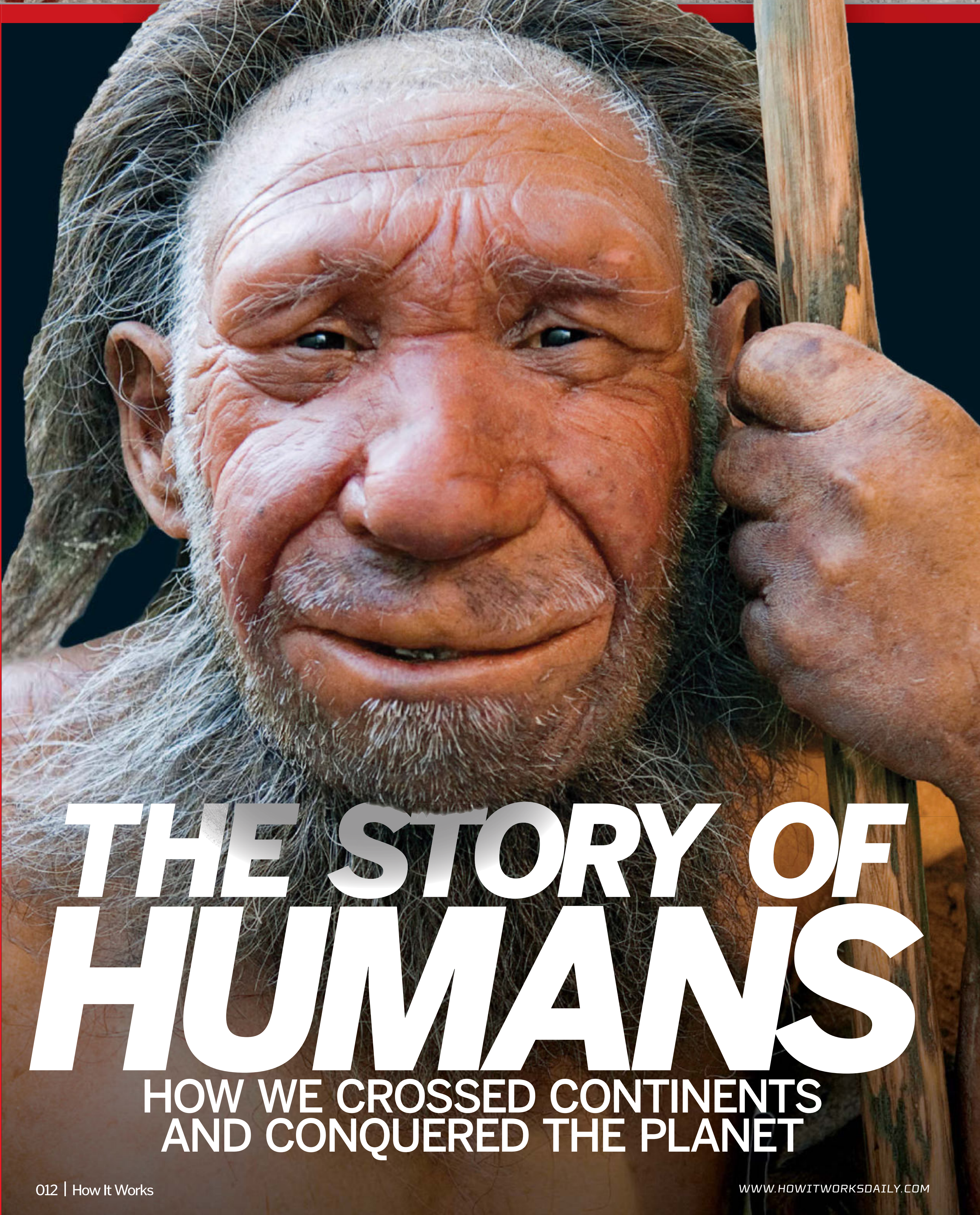
For the first time in history astronomers have directly observed a planetary birth, in the form of a giant gas exoplanet roughly 450 light years from Earth. The planet's nearest star is called LkCa 15 and is only 2 million years old, much younger than our Sun, which has been around for 4.5 billion years. Astronomers will closely monitor this planet's development, and hope to learn more as it slowly forms.

Vocal cords can be grown in the lab

Various injuries or diseases such as cancer can destroy vocal cords, but researchers at the University of Wisconsin-Madison have produced a lab-grown replacement. The team took cells from donated vocal cords and applied them to a 3D collagen scaffold. The cells grew to form functional vocal cord tissue that exhibits the same properties as the real thing.

London has solar-powered 'smart benches'

In London's Canary Wharf, park benches are now offering the public more than just a place to sit. A Serbian company called Strawberry Energy has designed and installed 'smart benches' for the general public, which provide a phone charging station powered by the Sun. This innovative seating also provides local information, such as listings for the nearest theatres and cinemas, and even has an emergency call button.



THE STORY OF HUMANS

HOW WE CROSSED CONTINENTS AND CONQUERED THE PLANET

In the iconic *March of Progress* illustration, human evolution is depicted as a single flowing process that begins with apes and ends with our modern selves. But in truth, our evolutionary past is a messier affair, involving an assortment of ancestors treading a multitude of paths that split, stumble and intersect in ambiguous ways.

When we draw family trees, each end branch represents a distinct species – a grouping of individuals that are genetically similar enough to interbreed. New species evolve through the process of natural selection: environmental pressures favour some traits over others, which causes populations to gradually adapt or diverge in order to have a better chance of surviving.

Despite a fragmentary fossil record, scholars have traced the evolution of hominins – that is, the group of species including modern humans and our ancient bipedal ancestors – back more than six million years. But field scientists are still uncovering 'new' extinct hominins, meaning that our understanding of human evolution is itself constantly evolving.

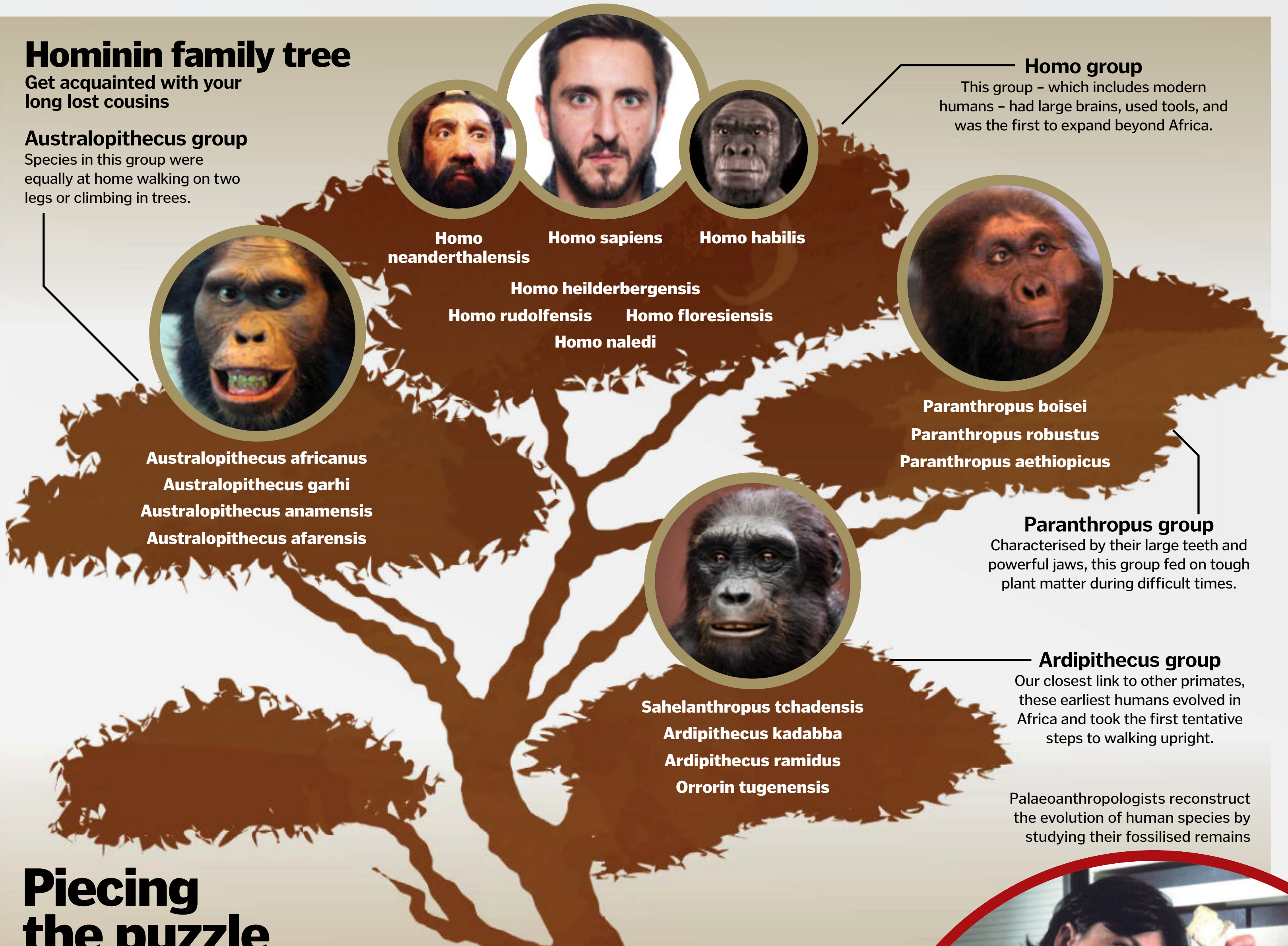
While we know that modern humans and chimpanzees diverged from a common ancestor between six and eight million years ago, scientists are still striving to find the earliest hominin and pin down the moment the two lineages split. Above all, they seek to answer the most fundamental question in human evolution: what sequence of events and adaptations occurred to transform apes into humans?

Hominin family tree

Get acquainted with your long lost cousins

Australopithecus group

Species in this group were equally at home walking on two legs or climbing in trees.



Homo group

This group – which includes modern humans – had large brains, used tools, and was the first to expand beyond Africa.

Paranthropus group

Characterised by their large teeth and powerful jaws, this group fed on tough plant matter during difficult times.

Ardipithecus group

Our closest link to other primates, these earliest humans evolved in Africa and took the first tentative steps to walking upright.

Palaeoanthropologists reconstruct the evolution of human species by studying their fossilised remains

Piecing the puzzle

Palaeoanthropologists are scientists who peer into our evolutionary past. As they try to piece together our family tree, their most important clues come from fossils – physical evidence of ancient hominins, like bones and teeth, which help to classify different species.

In order to reconstruct how species evolved, it is crucial to know how old these fossils are. However, the commonly used method of radiocarbon dating can only be used on specimens younger than 40,000 years old.

Instead, experts look at materials in close proximity to the fossils, such as the layers of rock they were discovered in. Careful study of local geology combined with chemical analysis allows fossils and artefacts within the layers to be dated.

In the last decade, DNA sequencing has revolutionised this field. Because genetic mutations happen at predictable rates and are passed from parent to child, fragments of ancient DNA can be compared to our own to reveal secrets about our ancestors' biology and behaviour.

The Homo genus

What set our closest relatives apart from earlier human species?

Every human on the planet today is a member of one single species: Homo sapiens. Together with our extinct ancestors and closest relatives, we are part of the broader genus of Homo, whose members all share unmistakably human traits.

The Homo genus emerged somewhere around three million years ago in Africa, when the region was home to at least 11 species of hominin. The oldest Homo fossil – dated at 2.8 million years old – was a member of the species Homo habilis. Its name means 'handy man', as it is believed to be the first hominin that used stone tools. Although it retained many of the ape-like body features of earlier Australopithecus, its brain was much larger.

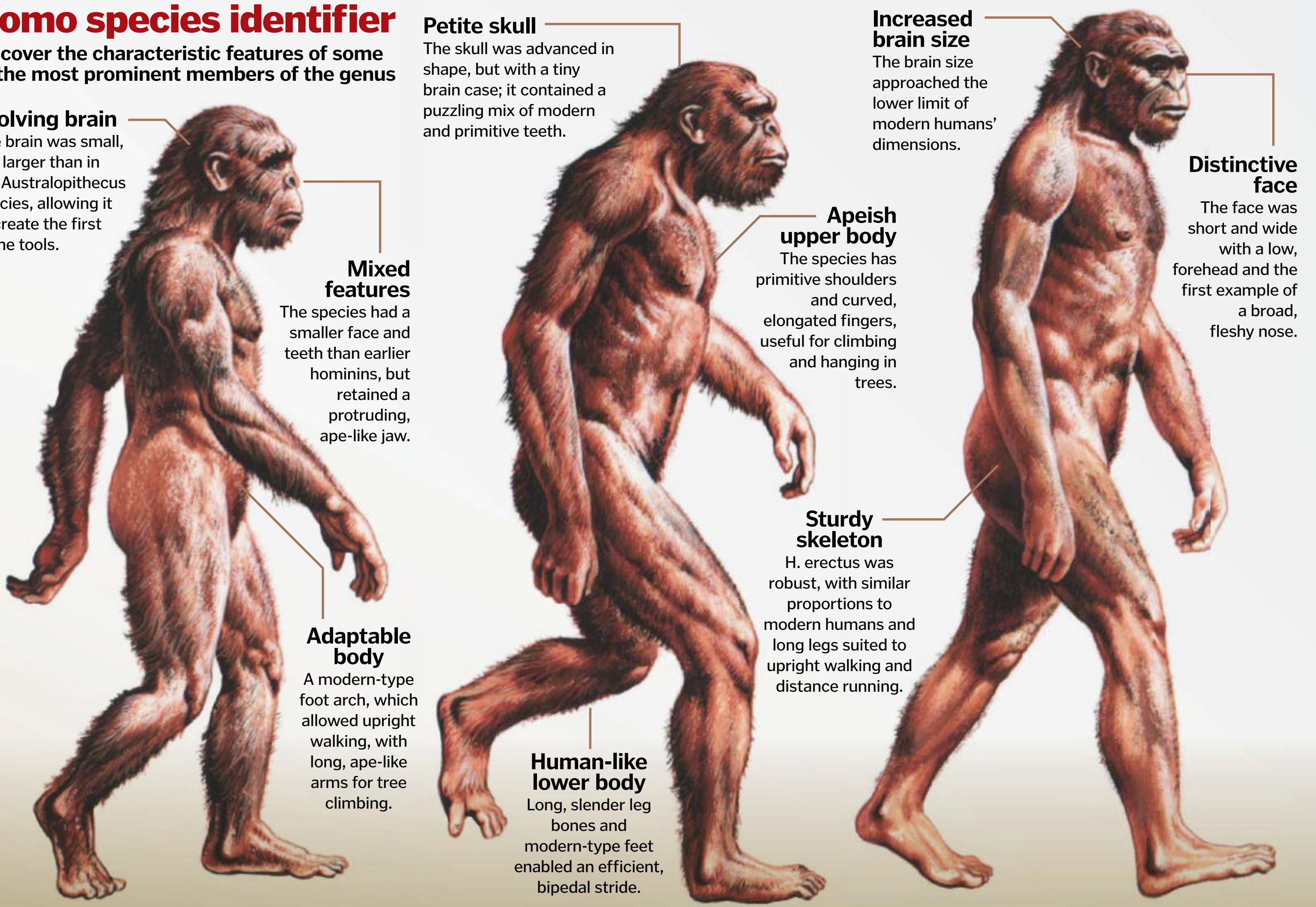
Tool use and brain size are two of the defining characteristics of the Homo genus. The third is an upright skeleton that enables walking on two feet. Together these changes gave an evolutionary edge in exploiting the environment, solving problems, and journeying over long distances.

Our own species is thought to have evolved 200,000 years ago from the strong, athletic Homo heidelbergensis. They in turn evolved from Homo erectus – one of the most successful hominins in history, surviving for two million years.

For a long time, scientists have argued over whether H. sapiens evolved within Africa before spreading around the world (the Out of Africa hypothesis) or evolved simultaneously in many locations (the multiregional hypothesis). Recent studies of DNA suggest we descend from a single population living 150,000 years ago, which heavily supports the Out of Africa theory.

Homo species identifier

Discover the characteristic features of some of the most prominent members of the genus



HOMO HABILIS	HOMO NALEDI	HOMO ERECTUS
Height: **1.1-1.2m** Weight: **30-36kg**	Height: **Approx 1.5m** Weight: **Approx 45kg**	Height: **1.45-1.8m** Weight: **40-68kg**
Average brain size: **610cm³**	Average brain size: **560 cm³**	Average brain size: **1,050cm³**

HUMAN HISTORY TIMELINE

6-8 MILLION YEARS AGO
Divergence of human and chimpanzee lineages from the last common ancestor.

6-7 MILLION YEARS AGO
Sahelanthropus tchadensis develops small canines, distinguishing it from apes.

6 MILLION YEARS AGO
Sahelanthropus walks upright, becoming the first bipedal hominin.

2-6 MILLION YEARS AGO
Brain size undergoes a slow, steady increase as bipedalism and tool use proliferate.

Did humans and Neanderthals interbreed?

In 2010, scientists announced a startling new twist in the human evolution story. Recently extracted fragments of Homo neanderthalensis DNA showed that 50,000 to 60,000 years ago – when they overlapped with modern humans in the Levant as they were flowing towards Eurasia – the two species occasionally interbred. In fact, the genome of everyone alive today who is not of African descent contains somewhere between one and four per cent Neanderthal DNA.

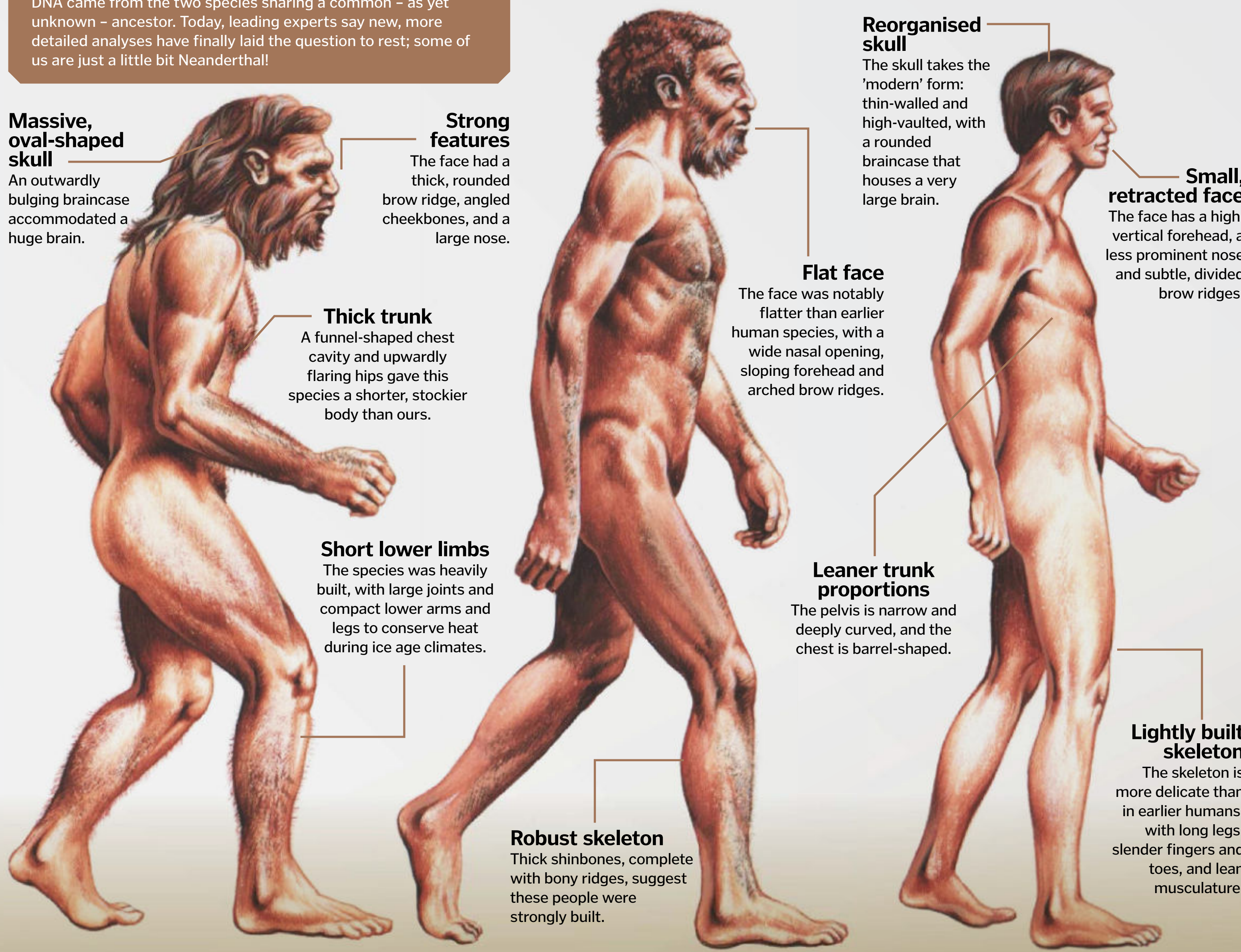
Neanderthals are our closest cousins, having also evolved from H. heidelbergensis. Although it is sometimes possible for two genetically similar species to have offspring together, some scientists were initially sceptical. They argued that the shared DNA came from the two species sharing a common – as yet unknown – ancestor. Today, leading experts say new, more detailed analyses have finally laid the question to rest; some of us are just a little bit Neanderthal!

Opposable thumbs

The grasping hands of our primate ancestors evolved as an adaptation to life in the trees. Opposable thumbs – which are able to move around and touch the other fingers – and flat fingertip pads both help tree-dwellers to grab on to branches as well as hold and manipulate small objects.

Our modern thumb has changed little since the last common ancestor of humans and chimpanzees. It is longer, compared to finger length, than any other primate's thumb, giving both strength and precision. This helped our ancestors gather a wide variety of foods and eventually develop tools.

An opposable thumb enables the hand to grip with strength and dexterity



HOMO NEANDERTHALENSIS
Height: **1.5-1.6m** Weight: **54-65kg**
Average brain size: **1,420 cm³**

HOMO HEIDELBERGENSIS
Height: **1.6-1.8m** Weight: **51-62kg**
Average brain size: **1,270cm³**

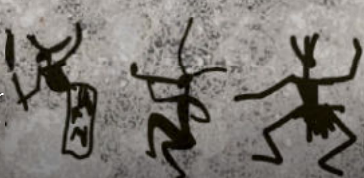
HOMO SAPIENS
Height: **1.6-1.8m** Weight: **62-78kg**
Average brain size: **1,350 cm³**

4 MILLION YEARS AGO
Human ancestors are mostly bipedal, but are also still comfortable in trees.

3-3.5 MILLION YEARS AGO
Many species of Australopithecus thrive within Africa.

3.3 MILLION YEARS AGO
Infant growth rate slows and starts to resemble that of modern humans.

2.8 MILLION YEARS AGO
The earliest known member of the Homo genus – Homo habilis – emerges in Africa.



Tools and development

How physical adaptations and new skills helped advance human species

Four major development trends separate humans from apes: terrestrialism, which is the move from tree-dwelling to ground living; bipedalism, the shift from moving on all fours to walking upright on two legs; encephalisation, which is an increase in brain-to-body mass ratio; and civilisation – a catch-all that includes social organisation, technological thought, communication and culture.

Separating cause from effect in these areas is tricky and experts disagree over the order in which they unfolded. But climate science offers some of the most compelling evidence for where it all started.

Beginning around ten million years ago, Africa's climate altered profoundly from lush tropical forests to sparse, open grassland. As food sources became more thinly distributed, walking on two legs would have enabled early humans to forage over long distances and even carry provisions for later. With reduced vegetation cover, standing upright would also have helped keep their bodies cool by reducing the exposed skin surface area, and moving more of the body up into the breeze and away from the hot earth.

Picking apart the other developments is more challenging. In particular, it isn't clear what spurred the expansion of the human brain. Mental skills perhaps became more important as a result of increasingly complex social interactions or the demanding technological thought required to produce stone tools. On the other hand, brain enlargement may only have been triggered once easily digestible, energy-dense food was available on a regular basis – in other words, after humans had figured out how to procure and cook meat. Homo species' digestive tracts then became shorter, freeing up energy for larger brains and bodies.

Tool-making became more systematic and the products more uniform; experts speculate that these increasingly ordered cognitive processes eventually led to organised language, symbolic thoughtand creative expression.

> "Humans have been using tools for at least three million years"

Thrusting spears gave Neanderthals the new predatory edge to hunt large prey

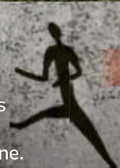
Lethal weapons

Traces of glue – perhaps tree sap or tar – found on Neanderthal-crafted stone points suggest that they were once attached to wooden shafts. Lashed in place with plant fibres, sinew, or leather, these would have made handsome spears, allowing Neanderthals to hunt larger prey from a safe distance, perhaps in cooperative groups.

2.6 MILLION YEARS AGO
The dawn of technology: hammerstones and cores are used to produce sharp flakes.

2.6 MILLION YEARS AGO
Stone tools give access to new foods, including meat from large animals.

2.5 MILLION YEARS AGO
Australopithecus africanus develops modern, shock-absorbing curve in lower spine.

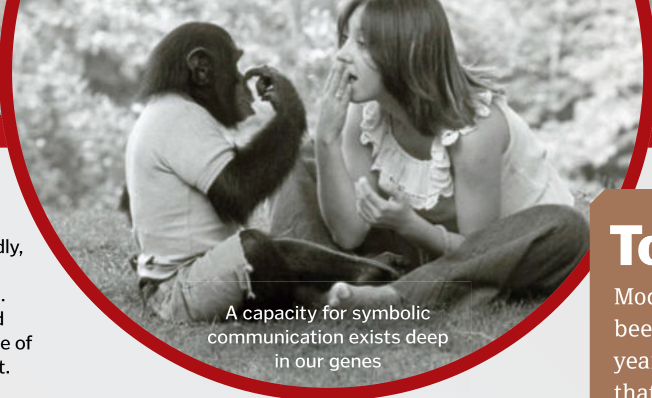


~2 MILLION YEARS AGO
Tools and food are transported to favoured resting and eating spots.

Culture

How did early humans make sense of their world? Sadly, fossils are silent on the subject of culture – language, rituals, music and other forms of symbolic expression. But shell beads made in Africa 100,000 years ago and 40,000-year-old cave drawings in Europe are evidence of our ancestors' impulse to create, express and connect.

40,000-year-old cave painting of a giant deer, in Lascaux, France



A capacity for symbolic communication exists deep in our genes

Communication

Many species communicate, but full language – with rules for combining sounds and words – appears to be uniquely human. One reason for this is that humans differ from most other primates in the way our larynx – or voice box – sits low in the throat. This allows us to shape sounds into speech, using our lips and tongues.

Precisely when and where language originated is unknown. The descended larynx evolved around 300,000 years ago, but experts believe spoken language only appeared in the last 100,000 years, probably developing out of a more basic 'proto-language' comprised of gestures and body language in addition to simple sounds.

Cooperation

When we work together cooperatively, we tend to achieve more in less time and with less effort. The same was true of our ancestors. By banding together, they could bring down larger animals in the hunt, forage a greater variety of foods, distribute tasks, defend resources and better protect the group from predators.

Early humans learnt to cooperate to bring down large prey

Brain size

In most mammals, brain size is proportional to body size. Most primates' brains exceed this ratio, but around two million years ago, our ancestors' brains started growing even larger. At the same time the brain was reordered, favouring the growth of some regions, such as those used for learning, over others, like those that govern smell.

Problem solving

As brain size and complexity increased, early humans became better equipped to tackle problems using logic and creativity. From tool-making to crossing continents to caring for the old and weak, it was this ability to interact with one another and the environment in novel ways that helped our ancestors survive in an unpredictable world.

Fire

Harnessing fire was a turning point in human history, but the evidence for how and when it happened is sparse and hotly contested.

Charred bones and ash suggest Homo ergaster interacted with fire in Africa as early as 1.5 million years ago, but whether the fires were wild or intentionally lit is a mystery. Better evidence of controlled use appears around 800,000 years ago; clusters of scorched tool-making debris, burned seeds, and wood mark more than a dozen early hearths across a site at Gesher Benot Ya'aqov in Israel.

Campfires not only provided warmth and protection from night-time predators; they also enabled food to be cooked, making it more digestible, and potentially influencing human brain evolution.

Tools of the age

Modern humans and our ancestors have been using tools for at least three million years. As intelligence increased, the tools that humans made became more sophisticated and specialised. Equipment for hunting, stripping animal carcasses and breaking open bones heralded an expansion in the ancient hominin diet, making more energy available for larger bodies and bigger brains.

Simple tools

Around 2.6 million years ago, early humans learnt to strike one stone with another to remove sharp-edged flakes. These simple tools represent a major evolutionary advance – the first technological thought. Toolmakers had to plan, learn from their mistakes, and select appropriate materials.

Refining the design

By 300,000 years ago, toolmakers understood how to prepare a stone 'core' so that flakes knocked from its surface with a single blow would have long, clean cutting edges. These could be refined for different purposes by tapping smaller flakes off one or both sides.

Intricate devices

Around 50,000 years ago, modern humans living in Ice Age Europe began working bone, ivory and antler into intricate and specialised tools including needles, spear tips, fishhooks and harpoons. These materials are awkward to work with, and the tools are a testament to the manual dexterity and mental acuity of their makers.

1.95 MILLION YEARS AGO
Homo erectus gives up climbing entirely, in favour of walking.

1.9 MILLION YEARS AGO
Newly carnivorous digestive tracts become shorter; brains and bodies become larger.

1.89 MILLION YEARS AGO
Homo erectus develops long legs and begins roaming faster and further.

1.8 MILLION YEARS AGO
Early humans develop a modern-type foot arch to support bipedal motion.

How we conquered the planet

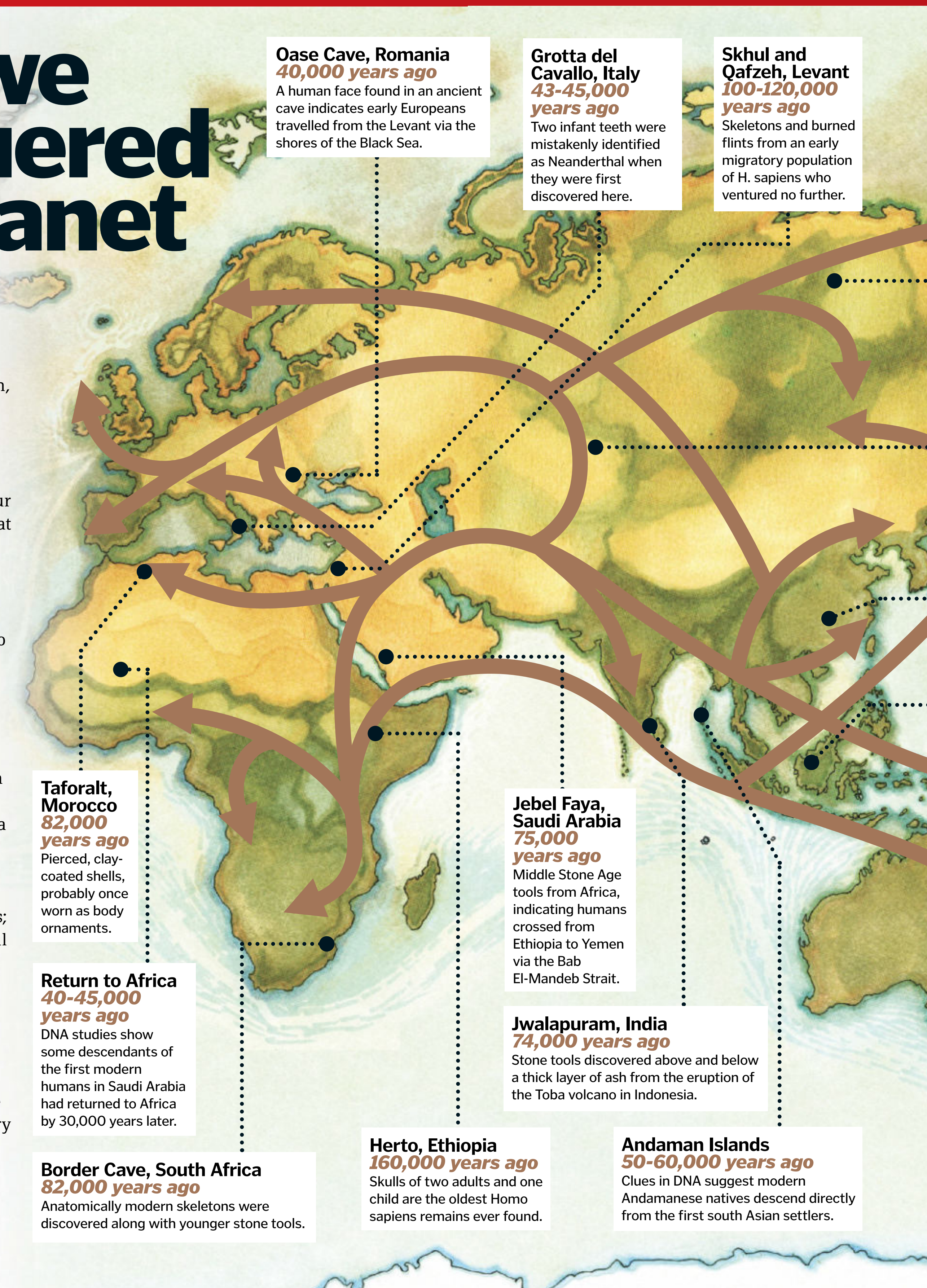
Humans went from African natives to citizens of the world

In our brief 200,000 years on Earth, Homo sapiens – unlike any of the human species before us – has managed to colonise the entire globe. But we were not the first to venture beyond Africa. Some of our ancestors took those initial steps at least 1.8 million years ago.

The first waves of adventurous hominins travelled east towards Asia, before eventually moving west and north into Europe. Homo erectus spread throughout Asia, reaching as far south as Java, and Homo heidelbergensis dispersed through both Asia and Europe.

As for our own species, all evidence suggests that we lived in Africa for the first 100,000 years of our 200,000-year existence. After a shaky first migratory attempt, it was another 30,000 years before we struck out again. This time marked the start of a mass exodus; Homo sapiens spread rapidly to all continents except Antarctica within 50,000 years, making us one of the most invasive species the world has ever known.

Why the itchy feet? Some scientists think we simply followed the roaming animals we ate; certainly other large predatory species made similar territorial expansions alongside us. Other experts hold the more romantic view that wanderlust is simply part of what makes us human.



Oase Cave, Romania
40,000 years ago
A human face found in an ancient cave indicates early Europeans travelled from the Levant via the shores of the Black Sea.

Grotta del Cavallo, Italy
43-45,000 years ago
Two infant teeth were mistakenly identified as Neanderthal when they were first discovered here.

Skhul and Qafzeh, Levant
100-120,000 years ago
Skeletons and burned flints from an early migratory population of H. sapiens who ventured no further.

Taforalt, Morocco
82,000 years ago
Pierced, clay-coated shells, probably once worn as body ornaments.

Jebel Faya, Saudi Arabia
75,000 years ago
Middle Stone Age tools from Africa, indicating humans crossed from Ethiopia to Yemen via the Bab El-Mandeb Strait.

Return to Africa
40-45,000 years ago
DNA studies show some descendants of the first modern humans in Saudi Arabia had returned to Africa by 30,000 years later.

Jwalapuram, India
74,000 years ago
Stone tools discovered above and below a thick layer of ash from the eruption of the Toba volcano in Indonesia.

Herto, Ethiopia
160,000 years ago
Skulls of two adults and one child are the oldest Homo sapiens remains ever found.

Border Cave, South Africa
82,000 years ago
Anatomically modern skeletons were discovered along with younger stone tools.

Andaman Islands
50-60,000 years ago
Clues in DNA suggest modern Andamanese natives descend directly from the first south Asian settlers.

1.8 MILLION YEARS AGO
Homo erectus becomes the first hominin to venture beyond Africa.

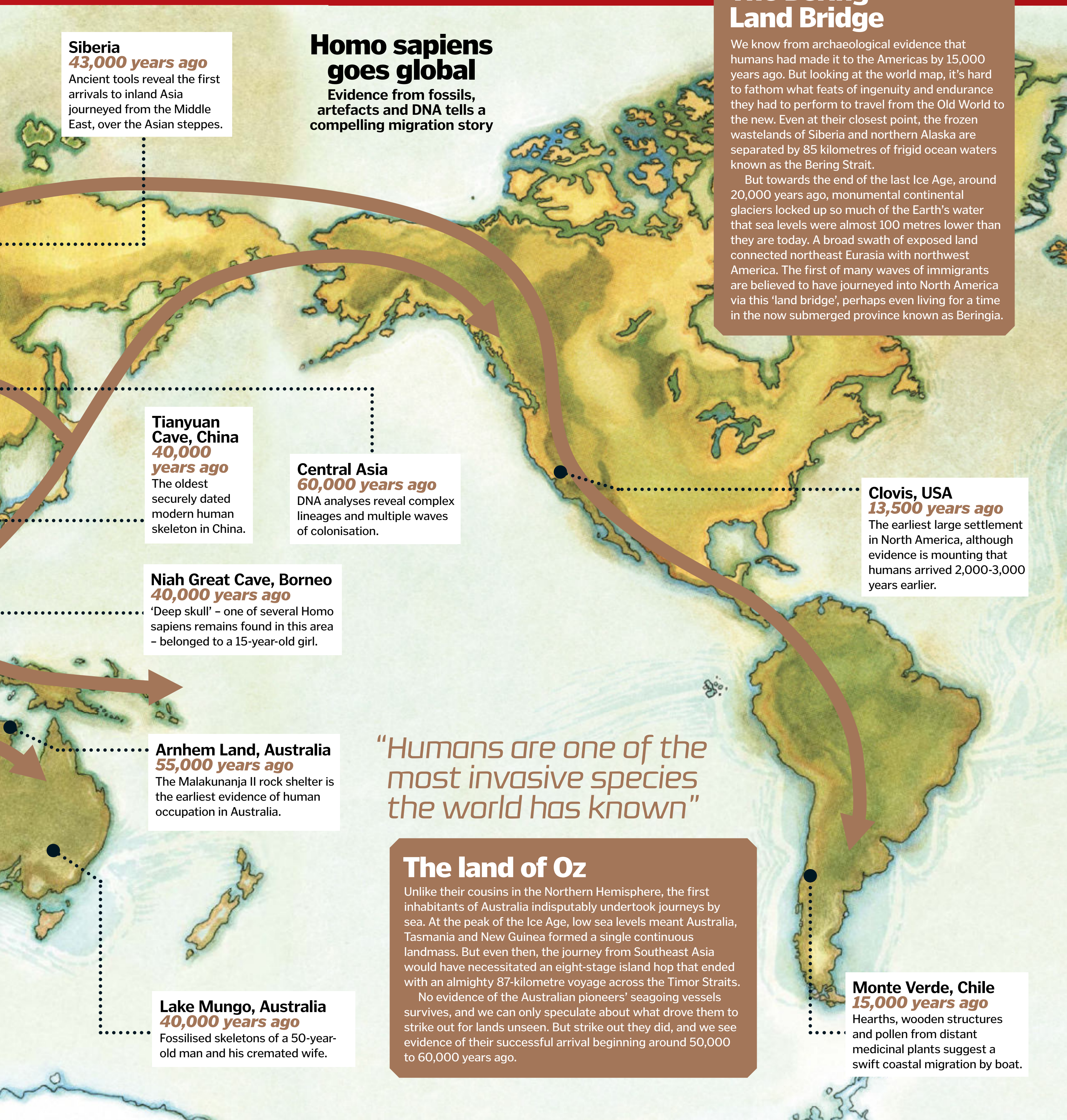
1.6 MILLION YEARS AGO
Neanderthals invent a hand axe – the first tool with well-defined form.

1.3 MILLION YEARS AGO
The Homo genus first spreads to Europe.

800,000 YEARS AGO
Early humans start to control fire and build hearths.

Homo sapiens goes global

Evidence from fossils, artefacts and DNA tells a compelling migration story



Siberia
43,000 years ago
Ancient tools reveal the first arrivals to inland Asia journeyed from the Middle East, over the Asian steppes.

Tianyuan Cave, China
40,000 years ago
The oldest securely dated modern human skeleton in China.

Central Asia
60,000 years ago
DNA analyses reveal complex lineages and multiple waves of colonisation.

Niah Great Cave, Borneo
40,000 years ago
'Deep skull' – one of several Homo sapiens remains found in this area – belonged to a 15-year-old girl.

Arnhem Land, Australia
55,000 years ago
The Malakunanja II rock shelter is the earliest evidence of human occupation in Australia.

Lake Mungo, Australia
40,000 years ago
Fossilised skeletons of a 50-year-old man and his cremated wife.

Clovis, USA
13,500 years ago
The earliest large settlement in North America, although evidence is mounting that humans arrived 2,000-3,000 years earlier.

Monte Verde, Chile
15,000 years ago
Hearths, wooden structures and pollen from distant medicinal plants suggest a swift coastal migration by boat.

The Bering Land Bridge

We know from archaeological evidence that humans had made it to the Americas by 15,000 years ago. But looking at the world map, it's hard to fathom what feats of ingenuity and endurance they had to perform to travel from the Old World to the new. Even at their closest point, the frozen wastelands of Siberia and northern Alaska are separated by 85 kilometres of frigid ocean waters known as the Bering Strait.

But towards the end of the last Ice Age, around 20,000 years ago, monumental continental glaciers locked up so much of the Earth's water that sea levels were almost 100 metres lower than they are today. A broad swath of exposed land connected northeast Eurasia with northwest America. The first of many waves of immigrants are believed to have journeyed into North America via this 'land bridge', perhaps even living for a time in the now submerged province known as Beringia.

"Humans are one of the most invasive species the world has known"

The land of Oz

Unlike their cousins in the Northern Hemisphere, the first inhabitants of Australia indisputably undertook journeys by sea. At the peak of the Ice Age, low sea levels meant Australia, Tasmania and New Guinea formed a single continuous landmass. But even then, the journey from Southeast Asia would have necessitated an eight-stage island hop that ended with an almighty 87-kilometre voyage across the Timor Straits.

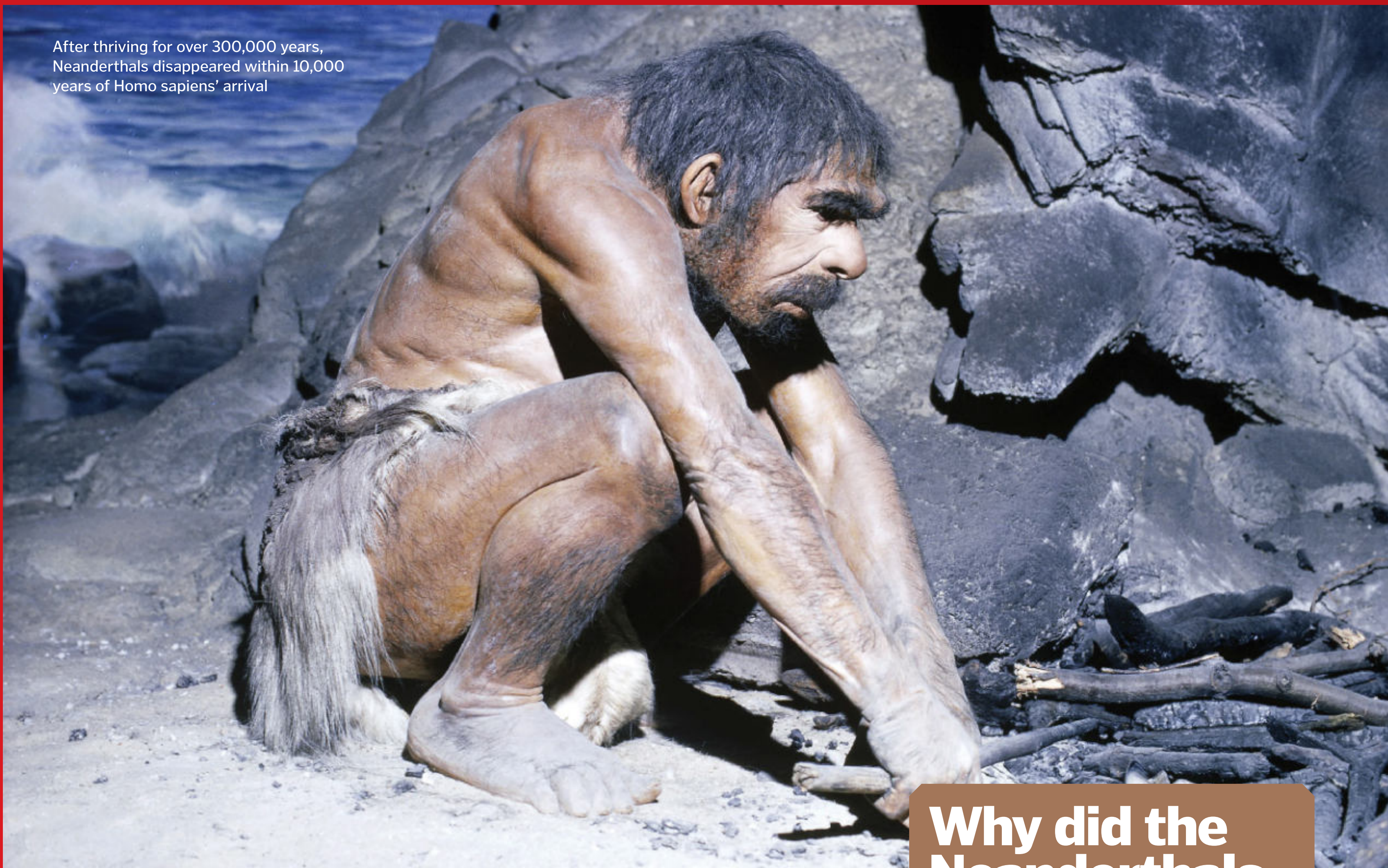
No evidence of the Australian pioneers' seagoing vessels survives, and we can only speculate about what drove them to strike out for lands unseen. But strike out they did, and we see evidence of their successful arrival beginning around 50,000 to 60,000 years ago.

200,000-800,000 YEARS AGO
Dramatic climate change spurs rapid evolution of larger, more complex brains.

400,000 YEARS AGO
Wooden spears are used to hunt large animals from safer distances.

400,000 YEARS AGO
Shelters are constructed to protect families or social groups from predators and elements.

300,000 YEARS AGO
Toolmakers produce long, clean blades by striking stone cores.



After thriving for over 300,000 years, Neanderthals disappeared within 10,000 years of Homo sapiens' arrival

Surviving adversity

How modern humans overcame threats and evaded extinction

After over six million years of human evolution, Homo sapiens is the only species left standing. What is the secret to our success? Scientists believe it lies in our adaptability, our capacity for abstract thought and our ability to cooperate.

Indeed, no other animal species has adapted to as wide a range of habitats and such divergent pursuits as modern humans. As successive waves flowed out of Africa and dispersed throughout the world, we learned in each new place how to find and eat local food and to survive different climate conditions.

We could not have done this without technological ingenuity, nor without the cultural transmission of ideas – the ability to mimic one another, communicate concepts, and learn new skills. This allows the work of the most skilled or intelligent to benefit entire populations, instead of forcing each new generation to re-invent the wheel.

These characteristics made us resilient in the face of change. During the Ice Age winters of 15,000 years ago, for example, modern humans in eastern Europe came up with clever ways to cope with the cold. By sewing clothes from animal hides, building shelters from mammoth bones, preserving dwindling food supplies in the permafrost and using fire to keep warm, they were able to ride out the tough times together and ensure the survival of the species.

Why did the Neanderthals die out?

Between 35,000 and 45,000 years ago, modern humans spread throughout Europe, while the Neanderthals, present since over 250,000 years earlier, mysteriously disappeared. Many scientists suspect the two events are closely linked, and argue that Homo sapiens out-competed their close cousins for resources and perhaps even actively attacked them.

Others wonder whether the narrow Neanderthal gene pool might have been to blame. Some studies suggest that the Neanderthal population never grew bigger than a few thousand individuals. The lack of genetic diversity and small population size would have made them vulnerable to infections, radical shifts in the environment and natural disasters.

250,000 YEARS AGO
Pieces of pigment are used as chunky crayons to communicate with symbols.

195,000 YEARS AGO
Homo sapiens evolves in Africa during a time of dramatic climate change.

160,000 YEARS AGO
Homo sapiens collects and cooks shellfish on the southern shores of Africa.

130,000 YEARS AGO
Modern humans exchange resources over long distances.

A thriving species

How soil, society and science elevated modern humans

The moment when modern humans transitioned from merely surviving to convincingly thriving happened somewhere around 12,000 years ago, coinciding with the advent of agriculture.

For millions of years leading up to this time, early and modern humans alike were preoccupied with foraging, hunting and scavenging food. But once we discovered that we could control the growth and breeding of certain plants and animals, we quickly became farmers and herders.

As these practices gained momentum, settlements began to form around them. These grew from villages to towns to cities as food became more plentiful. Within them, the human population began to explode, eventually reaching levels where we were unlikely to be wiped out by anything less than a global catastrophe.

Cities became the focus of social interaction, idea exchange and technological innovation. The ballooning population allowed knowledge and creative expression to flourish, as individuals were able to specialise and learn from each other.

Over centuries and millennia, the rate of progress has continued to accelerate and innovations – from the printing press to the Internet, from surgery to vaccines, from the wheel to global air travel – continue to make our lives longer, safer and more rewarding.

Humanity's vast accumulation of medical expertise keeps us healthier than ever before

Where are we headed?

Of course, the story of humans is not over. Pressures of diet and disease, as well as our increasingly globalised lifestyles, continue to influence our genetic trajectory. In fact, some scientists think human evolution is accelerating. So what does our future hold?

For the first time in history, genetic engineering may soon give us direct influence over our own or our children's genes. But superhuman bodies will be useless if we continue to neglect the planet that sustains us. Despite our miserable environmental track record, we have the unique ability to comprehend the future consequences of our actions; the question remains whether we can learn to look beyond our immediate, individual interests.

If the planet can't meet the needs of the heaving population, we might eventually have to turn our gaze outwards. Colonisation of space might even result in new species of humans developing as populations are isolated by distance and interbreeding becomes impossible.

Throughout history, humans have followed the urge to venture into the unknown

"The ballooning population allowed knowledge and creativity to flourish"

100,000 YEARS AGO
The first evidence of an intentional burial with ritual elements.

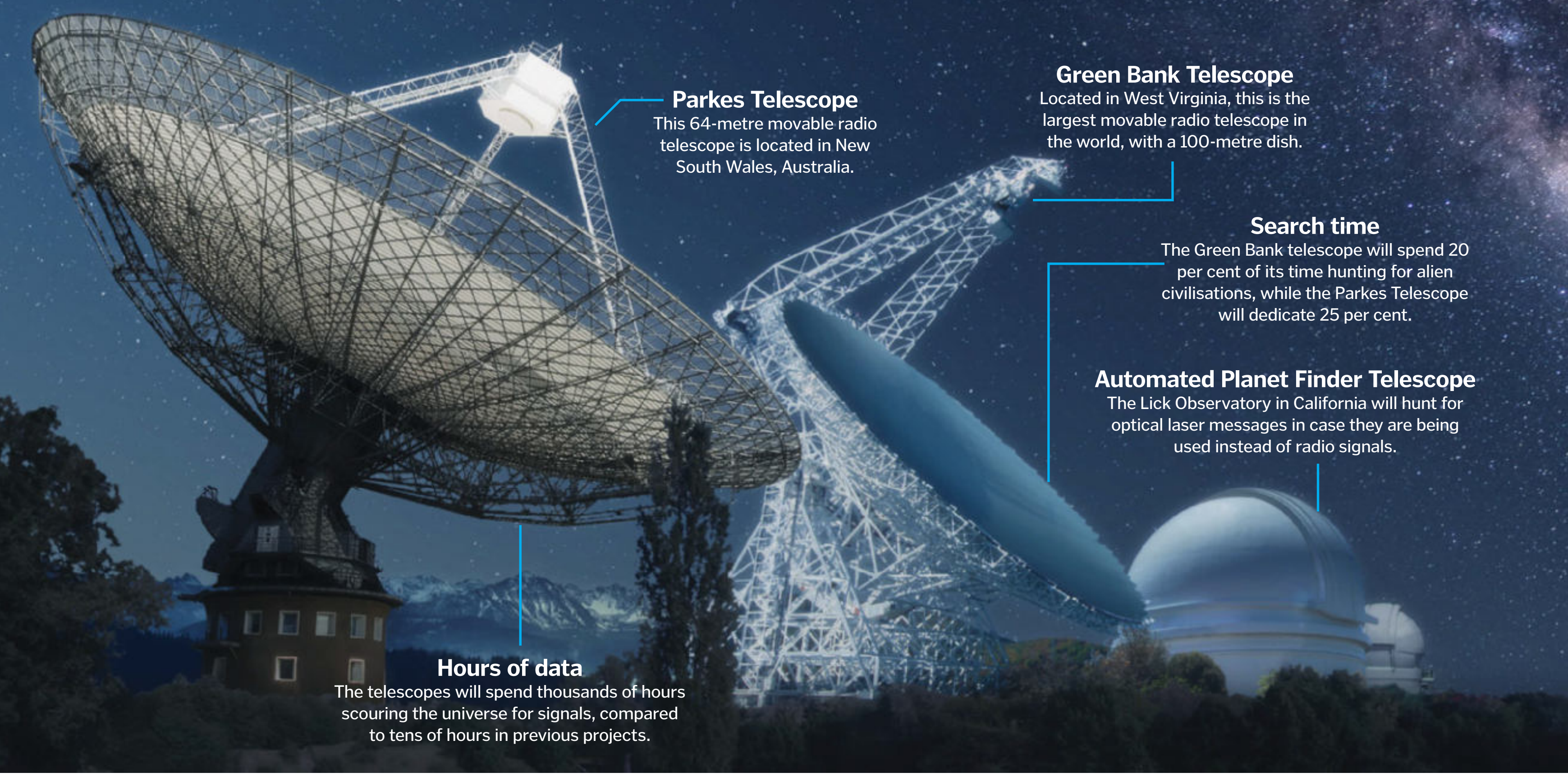
70,000 YEARS AGO
The major dispersal of Homo sapiens beyond Africa begins.

40,000 YEARS AGO
Modern humans create the first permanent drawings in Europe.

12,000 YEARS AGO
Agriculture begins to transform Earth's landscapes, first locally and then globally.

THE SEARCH FOR ALIEN LIFE

HOW THE GROUND-BREAKING SEARCH FOR LIFE COULD PROVE WE'RE NOT ALONE



In this possibly infinite universe, could Earth truly be the only inhabited planet? Are we really that special, or is the universe actually teeming with life? Could there be advanced civilisations out there trying to make contact right now? In July 2015, Russian entrepreneur Yuri Milner and renowned physicist Stephen Hawking announced an ambitious new initiative to search for communications from advanced alien worlds. Breakthrough Listen is described by the National Radio Astronomy Observatory as "the most powerful, comprehensive, and intensive scientific search ever for signs of intelligent life in the universe".

The initiative has set aside $100 million (£66 million) over ten years to listen for signals from the nearest million stars in the Milky Way, and from the nearest hundred galaxies around us. Led by a team of internationally renowned experts that includes Astronomer Royal, Lord Martin Rees, the project will use some of the world's largest and most powerful telescopes. The search is based on the idea that among the hundreds of billions of stars in our close galactic neighbourhood, there are thousands of planets similar to our own. With the right environment and optimal chemistry, many scientists believe that life could evolve on some of these distant Earths.

If life exists on other planets, so too might intelligent life, who like us, could be interested in exploring the universe around them, and in making contact. This is not the first time that Search for Extraterrestrial Intelligence (SETI) experiments have been attempted. Dr Frank Drake, author of the Drake Equation and one of the scientific leads on the Breakthrough Listen project, was among the first to start scanning for extraterrestrial life back in 1960. The Breakthrough Initiative builds upon more than 50 years of experience, allowing the team to look further and wider than ever before.

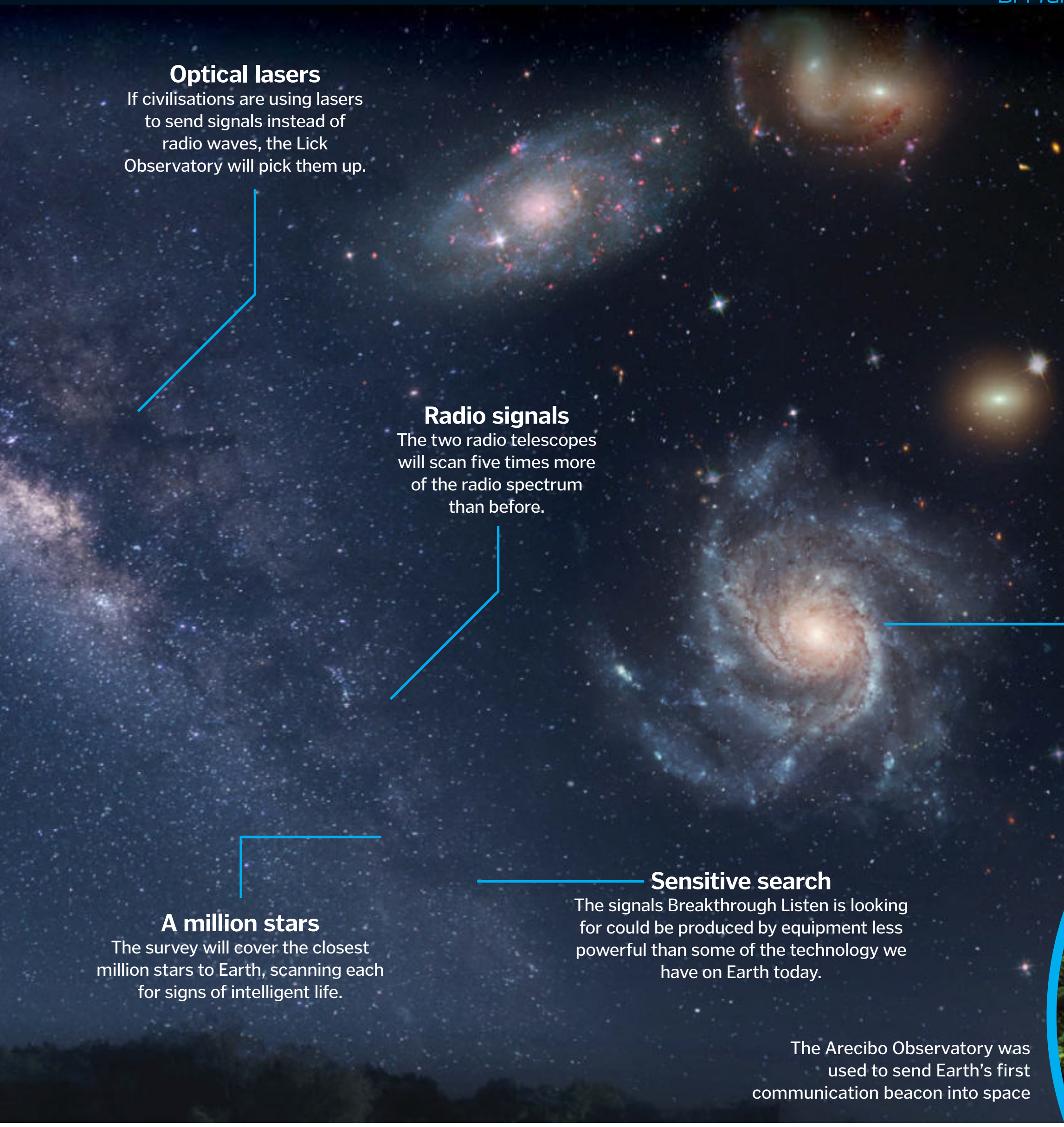
So far, we have no proof that life has ever existed on any planet other than Earth, but if we can find just one example elsewhere, it will completely change the way that we view the universe. As Frank Drake said at the Breakthrough launch, "Right now there could be messages from the stars flying right through the room, through us all. That still sends a shiver down my spine. The search for intelligent life is a great adventure. And Breakthrough Listen is giving it a huge lift."

DID YOU KNOW? *One of the first promising signals detected by a SETI experiment was actually from an American U2 spy plane*

Scanning for alien transmissions

Breakthrough Listen will use three of the world's most powerful telescopes

"The search for intelligent life is a great adventure"
Dr Frank Drake



The Arecibo Observatory was used to send Earth's first communication beacon into space

The search for intelligent life

We have begun searching for signs of life in our own Solar System, but the search for intelligent life is different. We can reach our neighbouring planets and moons with probes and rovers, allowing us to sample the atmosphere and the soil directly to find even the tiniest traces of biological materials. But to find out whether there is life beyond the reaches of our spacecraft, scientists must take a different approach. We cannot yet tell whether primitive life exists on distant planets, but if advanced, intelligent civilisations have developed the technology to send messages out into space, we might be able to detect their signals.

Four of the scientists behind Breakthrough Listen: (left to right) Martin Rees, Frank Drake, Ann Druyan and Geoff Marcy

SIGNS OF LIFE

What do we actually look for when searching for aliens?

The search for intelligent life focuses less on what aliens might be made of, and more on how they might communicate. Distant planets in other star systems are too far away to see clearly, but we can pick up signals released into space. But how do we know what to listen for? We live in the same universe, so we share the same fundamental physics and chemistry. Communications have to reach over vast distances, travelling through the dust and gas of the universe without being lost or degraded, and scientists think that it is most likely that they would be sent using radio waves or powerful optical lasers.

Listening out for every single signal across the entire electromagnetic spectrum would be impossible, so to detect these communications, we need to try to think like aliens. This was first attempted in 1959 by two scientists from Cornell University; Giuseppe Cocconi and Philip Morrison suggested focusing in on a specific frequency, the 1,420 MHz 'hydrogen line'. Hydrogen is the smallest and most abundant element in the universe, and when its energy state changes it creates a characteristic spectral line, which is always at a frequency of 1,420 MHz. This falls into the microwave radio region of the electromagnetic spectrum, and is able to travel through dust and gas that block the path of visible light. Looking at the universe in this frequency allows us to see through dark clouds that normally block our view.

Cocconi and Morrison reasoned that civilisations more advanced than our own would also have used hydrogen line emissions to map the universe around them. If intelligent life forms also realise that other civilisations might be tuning in to this special frequency, they might use it to try and send a message. Frequencies either side of the hydrogen line are also monitored, in case alien life forms choose to reserve 1,420 MHz for scientific use, and some SETI experiments, including Breakthrough Listen, also monitor for pulses of laser light in case they are used instead of radio.

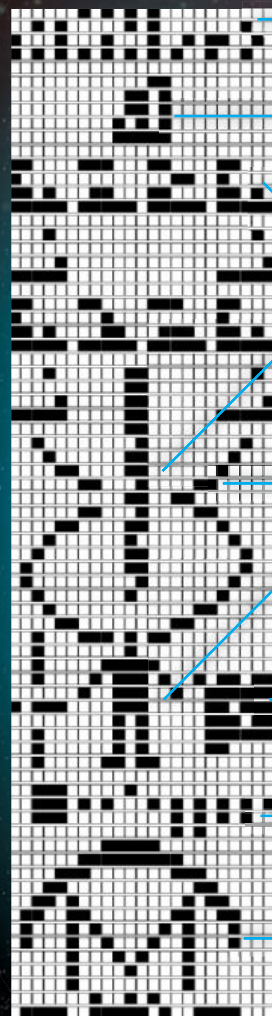
As the SETI Institute points out, "optical SETI requires that any extraterrestrial civilisation be deliberately signalling in the direction of our Solar System." This could happen by chance, but if aliens are signalling right at us, they might already know we are here.

We're over here!

The Arecibo Observatory greeted the universe in 1974

The Arecibo Message was a coded image sent out in the direction of 300,000 stars in the nearby M13 star cluster, over 40 years ago. It was constructed by shifting the frequency of the broadcast to spell out binary 0s and 1s. In less than three minutes, the message attempted to paint a picture of life on Earth for any intelligent life that might be watching.

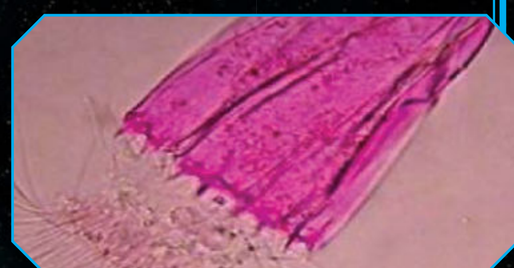
"Scientists are searching for planets and moons in the Goldilocks zone"



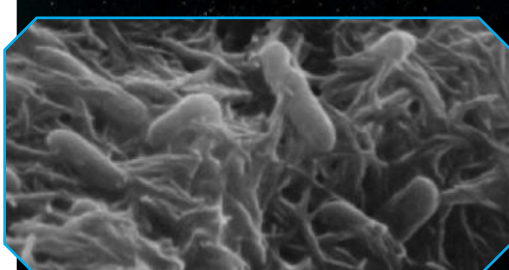
Extreme Earth life

Alien worlds needn't be exactly like ours; even on Earth, organisms survive in environments that are completely unsuitable for humans. Meet the Earth extremophiles.

Tardigrades
Tardigrades can survive without water, in extreme cold, under high levels of pressure or radiation, and even in the vacuum of space.



Animals that live without oxygen
In 2010, scientists reported three complex species living at the bottom of the sea, in an area known as a 'dead zone', where there is no oxygen.



Electric bacteria
Shewanella bacteria can use metal ions and other compounds to release energy, instead of oxygen. This is not seen in any other organisms on Earth.

Extremophiles
Many other species thrive in extremes. For instance, thermophiles survive at high temperatures, and acidophiles withstand acidic conditions.

How to hunt for aliens

There are billions of stars in our galaxy alone, but which should we focus on?

The first step in the search for life is to define what life actually is. This is still a topic of debate, but it is generally agreed that living things are complex and organised. They use resources from their environment to generate energy, and build molecules for replication and growth. They react to their surroundings, adapt and reproduce, all of which requires complex chemistry.

The most abundant elements in the universe are hydrogen and helium, but helium does not form molecules with other elements, and hydrogen can't make complex molecules on its own. Oxygen and carbon are the next most plentiful, and together with hydrogen are the most abundant elements in Earth's organisms.

It might seem a bit egocentric to assume that life elsewhere in the universe will be based on the same components as life on Earth, but a closer look at the chemistry reveals why scientists are so focused on finding carbon and water. Carbon can make four bonds to other elements, providing the scaffold that allows complex molecules to be made. This property can be matched by silicon, but the chemistry is not quite the same. While we exhale carbon dioxide, a silicon-based equivalent might exhale sand.

Water provides a solvent in which these large, complex molecules can dissolve, enabling them to interact. Water is also good at maintaining stable temperatures, and the fact that ice floats means that lakes don't freeze solid. These properties are hard to match, although ammonia and hydrogen fluoride come close.

Given what we know about the chemistry and composition of the universe, scientists are searching for planets and moons in the so-called 'Goldilocks zone' or 'habitable zone', where liquid water might exist. If these conditions can support life on Earth, why not elsewhere?

Life in our Solar System

We might not have to look far to find aliens

Mars
NASA's rovers have shown that Mars was once home to vast pools and rivers, and in 2015, NASA confirmed that liquid water still flows on the Red Planet today.

Europa
Jupiter's icy moon may have a salty ocean beneath its surface. NASA believes that it touches the moon's rocky core, providing chemical elements that could sustain life.

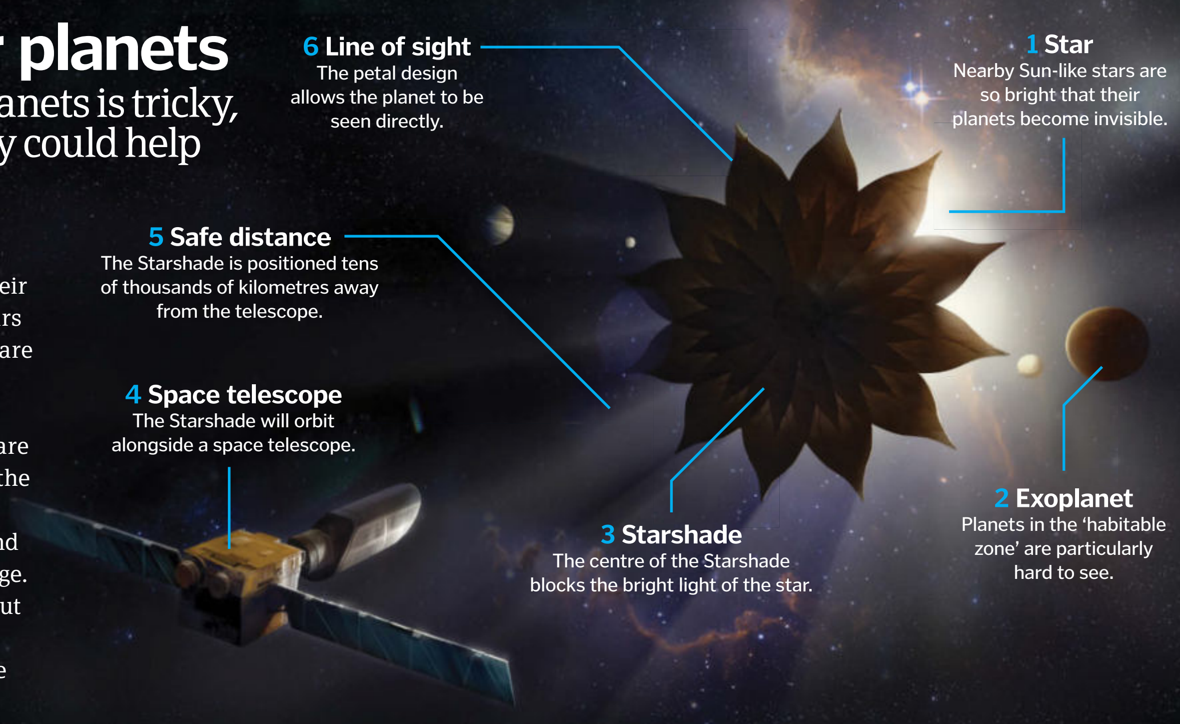
Enceladus
Saturn's moon Enceladus releases jets from its icy surface. Scientists believe that they could be carrying materials from a hidden liquid water ocean underneath.

Titan
Saturn's largest moon has an atmosphere of nitrogen and methane that intrigues scientists. Some suggest that methane-based life forms could inhabit Titan's seas.

Hunting for planets

Spotting distant planets is tricky, but new technology could help

To identify Earth-like planets elsewhere in the galaxy, scientists watch out for their shadows as they pass across their parent stars, but the closest stars are so bright that their planets are a real challenge to detect. The private aerospace and defence company Northrop Grumman are developing a screen known as the 'Starshade', which will fly in between orbiting telescopes and the stars they are trying to image. The petal shape should block out most of the star's light, letting only the reflected light from the planets pass through.



ARE WE ALONE IN THE UNIVERSE?

Top scientists think that Earth is just one of many inhabited planets

There are billions of stars in the universe, and some astronomers think it's likely that each one in the Milky Way galaxy has at least one planet. The director of the Space Telescope Institute in Baltimore, Matt Mountain, told NASA: "What we didn't know five years ago is that perhaps ten to 20 per cent of stars around us have Earth-size planets in the habitable zone." Being in the right zone is one thing, but being home to life is another. And being home to intelligent life with the technology to send signals out into space is something quite different again.

On Earth, moving from single-celled organisms like bacteria, to complex, multicellular organisms, like worms, fish, and humans took around 2.5 billion years, and it only happened once. As Professor Stephen Hawking pointed out in a lecture entitled Life in the Universe, "This is a good fraction of the total time available, before the Sun blows up." Assuming that life can get past this bottleneck, at least one species then needs to become intelligent enough to want to communicate with the universe. If this is possible, where is everybody? This question, known as the Fermi Paradox, was asked by Enrico Fermi in 1950. He argued that technologically advanced civilisations could colonise entire galaxies in just ten million years, fractions of the age of the Milky Way, so we really should have seen evidence of them by now.

It could be that there really are no other intelligent life forms in the galaxy, but there are dozens of other explanations. One of the most widely discussed is the idea that intelligent life might not survive long enough to make contact; it could be that asteroid impacts, supernova blasts, natural disasters and warfare wipe intelligent life forms out before they have a chance to explore. Ultimately, the lifespan of a civilisation is limited by the life of its parent star, unless of course, the life forms find a way to leave.

> "Being in the habitable zone is one thing, but being home to life is another"

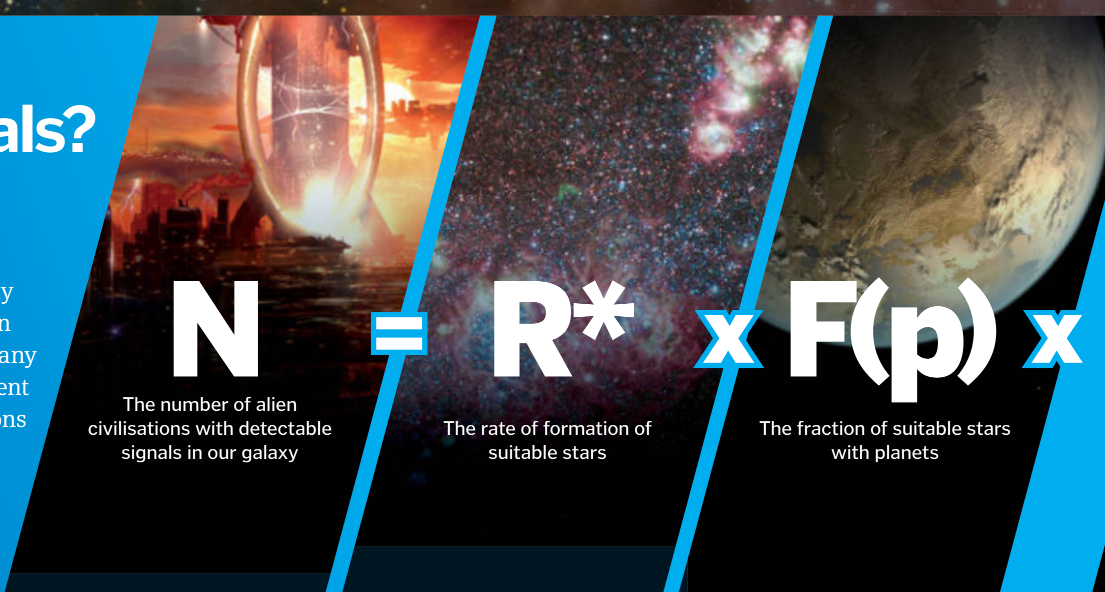
Have there always been Earth-like planets?

The universe is nearly 14 billion years old, but it hasn't always been able to sustain life. In the early days, as everything began to cool after the Big Bang, there were only two elements available: hydrogen and helium. These simple elements are not sufficient alone to build any kind of life. These gases formed the first stars and galaxies, and these new nuclear reactors smashed the small atoms together to make heavier elements like carbon and nitrogen. When these stars exploded, the new elements went on to form new stars. Our Solar System formed around 4.6 billion years ago, and star-forged elements like silicon and iron make up the planet that we live on. Until recently, scientists thought that the oldest stars wouldn't have Earth-like planets, but NASA's Kepler Space Telescope has found some that are orbiting stars more than twice the age of the Sun.


Kepler 452b orbits in the habitable zone around a star 1.5 billion years older than the Sun

How many worlds could send us signals?

Dr Frank Drake is a pioneer of SETI, and his equation uses probability to estimate the number of inhabited planets in the Milky Way that may be trying to make contact. It takes the rate of star formation in the galaxy and asks, how many of those stars have planets? Then how many of those planets are habitable, and how many of those are inhabited? Then how many have intelligent inhabitants? Finally, how many intelligent civilisations are actually sending signals? And for how long?



N = R* x F(p) x

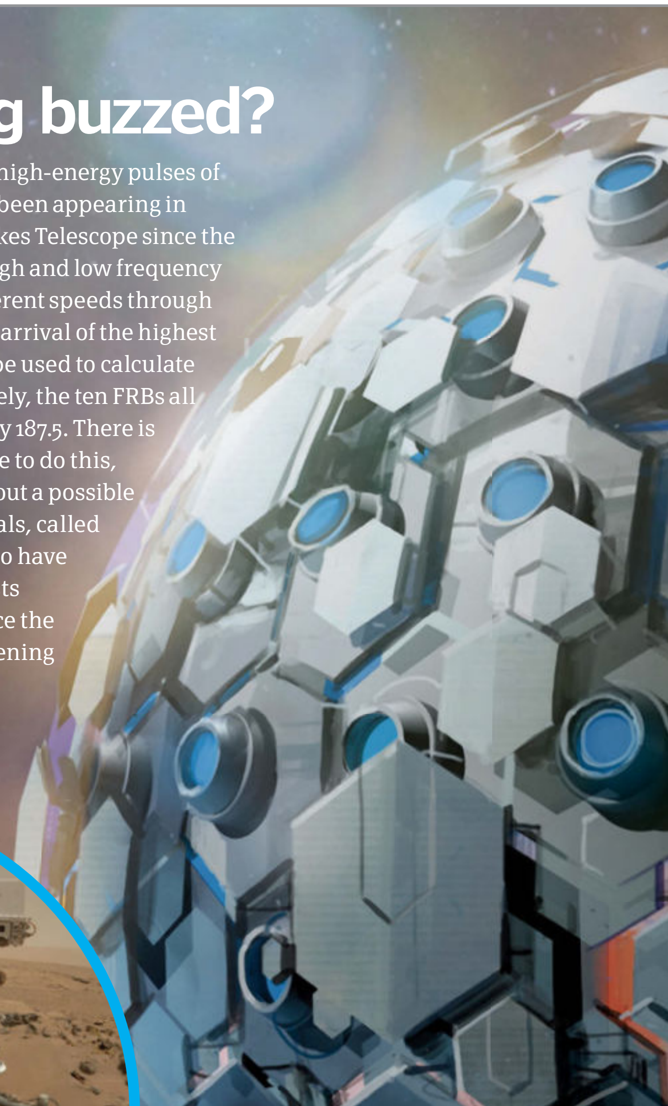
N: The number of alien civilisations with detectable signals in our galaxy

R*: The rate of formation of suitable stars

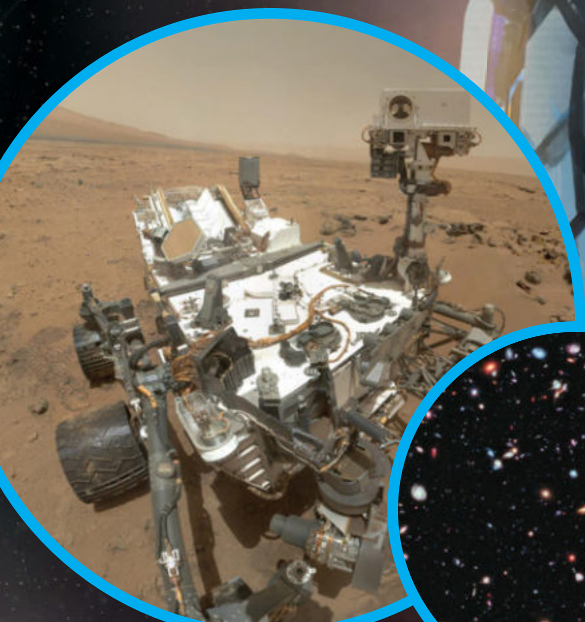
F(p): The fraction of suitable stars with planets

Are we being buzzed?

Fast radio bursts (FRBs) are brief, high-energy pulses of electromagnetic waves that have been appearing in scientific data gathered at the Parkes Telescope since the early 2000s. The bursts contain high and low frequency wavelengths, which travel at different speeds through space, and the delay between the arrival of the highest and lowest frequency waves can be used to calculate the distance to the source. Strangely, the ten FRBs all had delay times nearly divisible by 187.5. There is no natural object known to be able to do this, leading scientists to speculate about a possible alien source. However, other signals, called perytons, have since been found to have much more local origins – scientists discovered that they could produce the same interference patterns by opening the door of the microwave oven.



A Dyson Sphere is one idea for an alien megastructure, designed to capture the energy emitted by a star



Rovers, like NASA's Curiosity, are scouring Mars to see whether it was, or is, capable of supporting life

Every dot in this image is a galaxy with millions or billions of stars

Will we find alien life?

Top scientists think that life is out there, but it could be hard to find

MANY SCIENTISTS BELIEVE THERE COULD BE ALIENS….

- "What is the likelihood that only one ordinary star, the Sun, is accompanied by an inhabited planet? … To me, it seems far more likely that the universe is brimming over with life." ***– Carl Sagan, Cosmos***
- "To my mathematical brain, the numbers alone make thinking about aliens perfectly rational" ***– Stephen Hawking***
- "I think we're going to have strong indications of life beyond Earth within a decade, and definitive evidence within 20 to 30 years," ***– Ellen Stofan, NASA chief scientist***
- "I think life is common in the universe. We *may* be the only civilisation in the Milky Way. There *will* be other civilisations in the universe" ***– Brian Cox***

…BUT PROVING IT COULD BE A CHALLENGE

- "We have a galaxy full of ten billion planets, in habitable zones, roughly Earth-size… no visits, no communications… How can that be?" ***– William Borucki, ex-NASA Kepler scientist***
- "Life outside of Earth is probably going to be really hard to find… We can't even agree on a definition of what life detection is." ***– John Grunsfeld, NASA***
- "Right now there are maybe only 10,000 civilisations we can detect in the galaxy. That's one in ten million stars. We have to look at ten million stars before we have a good chance of succeeding." ***– Frank Drake***

IT COULD EVEN BE DANGEROUS

- "Active SETI is not scientific research. It is a deliberate attempt to provoke a response by an alien civilisation whose capabilities, intentions, and distance are not known to us." ***– Michael Michaud, International Academy of Astronautics***

N(e) x F(l) x F(i) x F(c) x L

N(e): The number of planets in each system that could support life

F(l): The fraction of suitable planets that are actually inhabited

F(i): The fraction of alien civilisations with detectable electromagnetic signals

F(c): The fraction of intelligent civilisations that develop technology to send signals

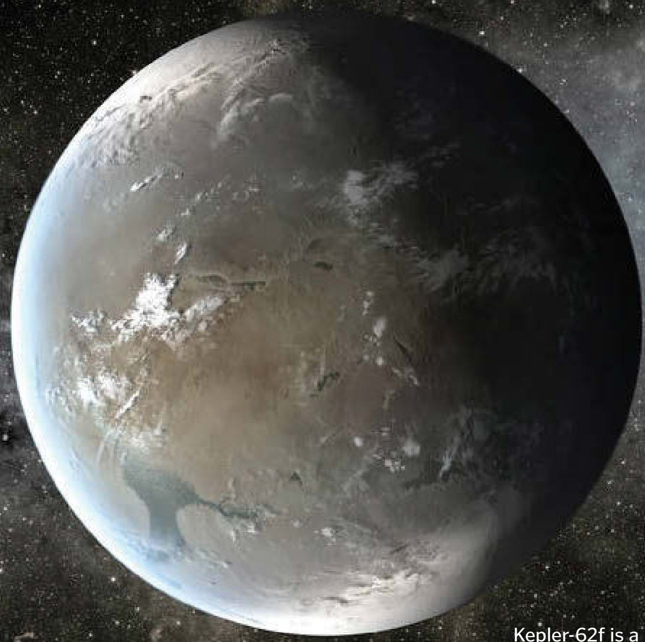
L: The length of time that the civilisations actually transmit signals into space

What makes a planet habitable?

Discover what makes Earth so special that it can support life

For life to exist on a planet, there's a bit of a *Goldilocks* situation. The conditions can't be too hot or too cold, with somewhere in the region of -15 and 115 degrees Celsius being about right. Within this range, liquid water can exist, and therefore, in theory, so can life.

In order to be at this optimum temperature, a planet must be the right distance from its host star. This is known as a habitable zone, and lies closer to smaller, cooler stars than large, hot ones. If the habitable zone is too close to a star, stellar flares can destroy the planet's atmosphere, which is needed to keep it warm and protect it from radiation and meteorites. To maintain an atmosphere, a planet must be the right mass to have enough gravity to hold on to it, and needs a magnetic field to protect it from stellar flares. It is believed that Earth's magnetic field is driven by the flow of molten iron in its outer core, so a planet's structure is also a key criterion for supporting life.



Kepler-62f is a super-Earth-size planet in the habitable zone of a star

What is a gravitational well?

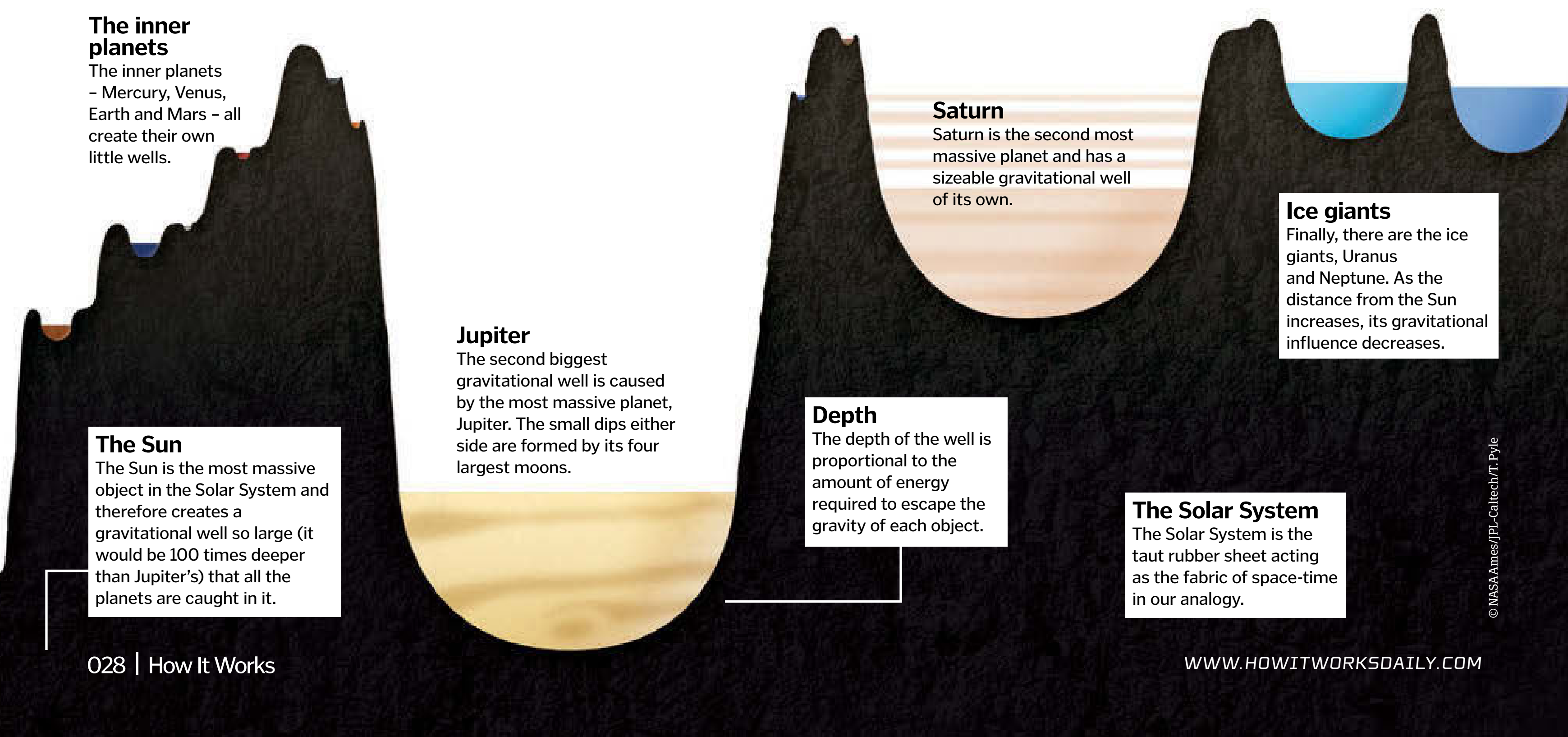
How this invisible force shapes the universe

While we are all familiar with gravity being the force that causes a dropped phone to clatter to the ground, Albert Einstein was the first to describe gravity as what happens when space is warped around a mass, creating a dip called a gravitational well. To better understand this, think of a large rubber sheet, held taut. The sheet acts as an analogy for space-time. Then take a bowling ball – which will act as a planet in our example – and place it on the rubber sheet. The sheet will dip and bend with the mass of the ball, forming a concave shape – the gravity well.

Now put a marble on the sheet, which represents a smaller object in space such as a comet or an asteroid. It creates its own gravity well, but it's much smaller than that of the bowling ball. If the marble gets anywhere near the larger gravitational well, it will roll into it – seemingly 'pulled' by gravity.

Everything with mass is able to bend space and the more massive an object is, the more it bends. An object can only escape a gravitational well if it is moving fast enough. Moons and satellites that orbit planets, for example, do not fall any further into the gravitational well of the planet they orbit.

The Solar System's gravitational wells



Star versus planet

The difference between the two is not as clear-cut as you might think

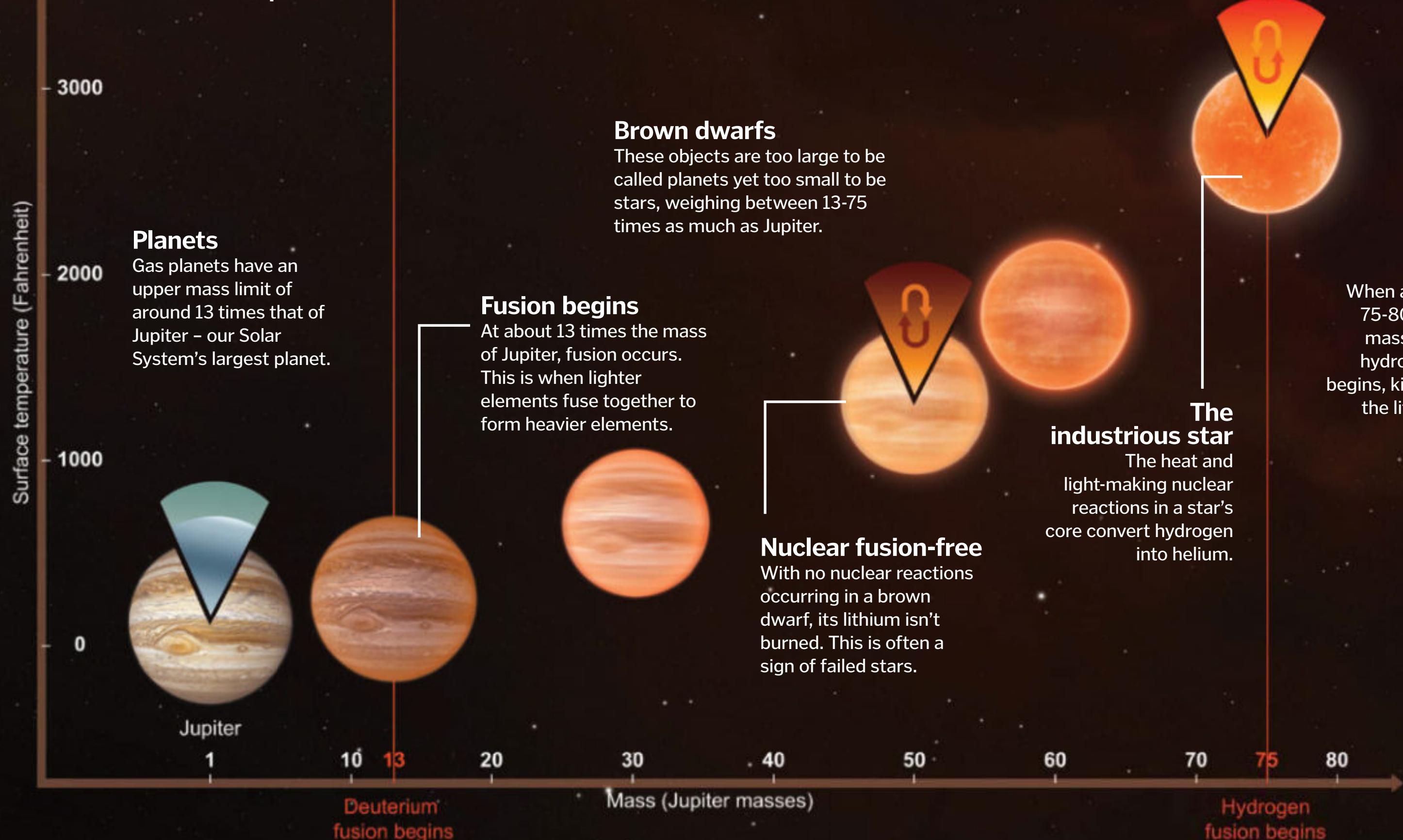
A star and a planet differ in the way that they form. Stars are born in large clouds of gas that collapse due to the inward force of gravity. From this, a rotating ball forms, attracting more gas from the surrounding cloud, which squashes the gas at the centre. Such an intense compression triggers nuclear reactions, igniting the star and causing it to release the energy we see as a star's light.

In order for a star to be made, it must have enough mass. If it doesn't, then gravity is unable to compress the gas enough to trigger the nuclear reactions needed to make light. You may have heard of a 'failed star', which is another name for a brown dwarf, a gaseous object with less than about eight per cent of the Sun's mass. If the mass is lower than that, we're getting into the territory of a gas planet.

Like stars, planets are also made by pulling material from a cloud to create their bulk, only this time the gas doesn't come from the cloud directly. Instead, planets accumulate material from the discs of gas and dust that surround newborn stars. That's why you're most likely to find a planet in orbit around a star – although it is also possible for a planet to become ejected from its system!

How to tell them apart

It's all about temperature and mass



Could brown dwarfs just be ejected planets?

The idea that brown dwarfs could just be worlds ejected from their home system rather than being failed stars is something that astronomers have considered. It is reasoned that, since planets are made from within a disc, they shouldn't possess one of their own. However, studying brown dwarf candidates using both ground and space-based telescopes, it has been found – in most cases – that signals detected from these brown dwarfs are similar to those from young stars. This means that brown dwarfs can have discs and therefore formed like stars rather than planets.

Brown dwarfs form just like stars, according to astronomers

Planets often form in discs of gas and dust found around young stars

YOUR GUIDE TO

How these chemical building blocks make up life, the universe and everything

All of the 118 elements in the periodic table are made from the same three key ingredients – protons, neutrons and electrons. The protons and neutrons make up the nucleus at the centre of each atom, while the electrons whizz around the outside and make chemical bonds with other atoms. The identity of each atom is determined by the number of protons in its nucleus, known as the atomic number. Hydrogen has one, helium has two, lithium three, and so on. The periodic table lists the elements in this order.

Protons are positively charged, while electrons are negatively charged; an atom will have an equal number of each. The electrons are arranged in 'shells' around the nucleus. Each row of the periodic table represents a new layer of electron shells, and each column represents how full the outer shell is. For example, elements in the first column of the periodic table – including lithium and sodium – have just one electron in their outer shell, while those in the second column – such as beryllium and magnesium – have two.

The number of electrons in the outer shell affects how the element behaves, so those in the same column have similar properties. Atoms like to have a full outer shell of electrons, so those with one or two extras are keen to give them away, and those with gaps want to fill them up. If you drop any of the elements from the first column into water, they will fizz, flame or even explode as they race to share their spare electron with other atoms, but if you did the same with the elements in the last column, nothing would happen. These elements have a full outer shell, so don't need to share their electrons with other atoms.

Most of the elements in the periodic table occur naturally on Earth, but any element heavier than lead (number 82) is unstable and gradually undergoes radioactive decay. Elements heavier than uranium (number 92) have to be made artificially. Join us as we explore the periodic table, and delve into the elements that shape our everyday lives.

How to read the periodic table

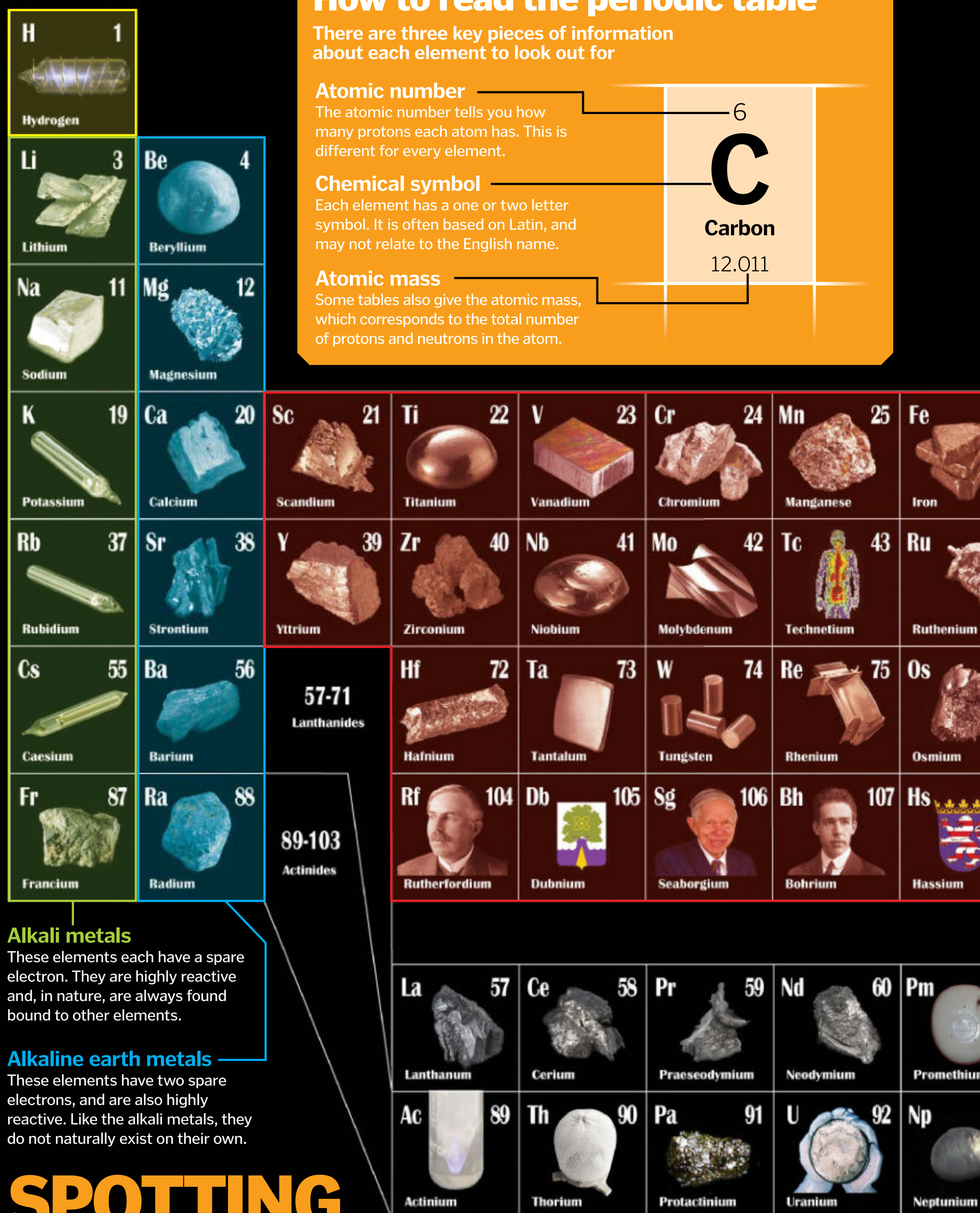
There are three key pieces of information about each element to look out for

Atomic number
The atomic number tells you how many protons each atom has. This is different for every element.

Chemical symbol
Each element has a one or two letter symbol. It is often based on Latin, and may not relate to the English name.

Atomic mass
Some tables also give the atomic mass, which corresponds to the total number of protons and neutrons in the atom.

6
C
Carbon
12.011



Alkali metals
These elements each have a spare electron. They are highly reactive and, in nature, are always found bound to other elements.

Alkaline earth metals
These elements have two spare electrons, and are also highly reactive. Like the alkali metals, they do not naturally exist on their own.

SPOTTING PATTERNS

The chemical elements have more in common than you might think

THE ELEMENTS

Filling in the gaps

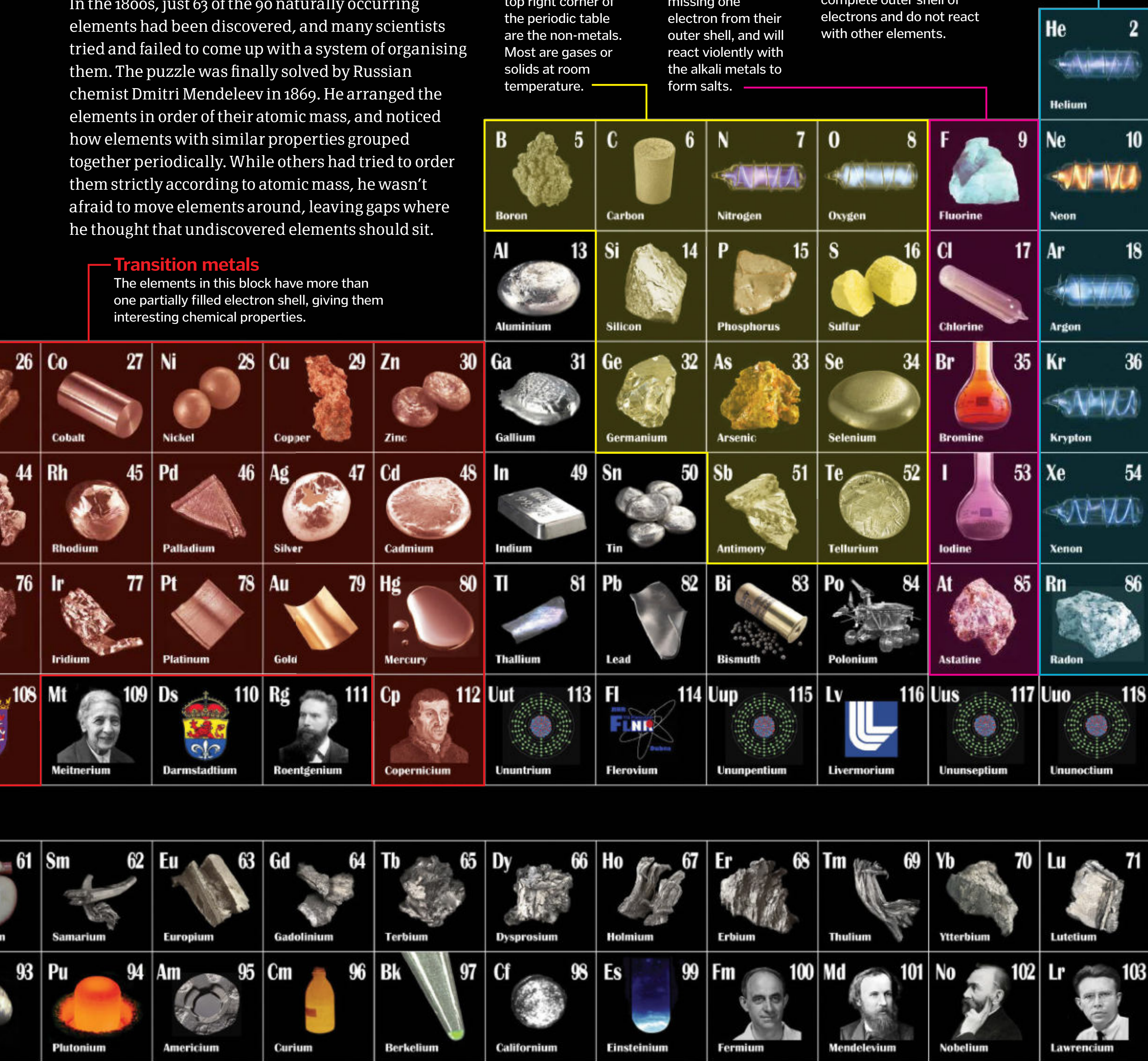
In the 1800s, just 63 of the 90 naturally occurring elements had been discovered, and many scientists tried and failed to come up with a system of organising them. The puzzle was finally solved by Russian chemist Dmitri Mendeleev in 1869. He arranged the elements in order of their atomic mass, and noticed how elements with similar properties grouped together periodically. While others had tried to order them strictly according to atomic mass, he wasn't afraid to move elements around, leaving gaps where he thought that undiscovered elements should sit.

Non-metals
The elements in the top right corner of the periodic table are the non-metals. Most are gases or solids at room temperature.

Halogens
The halogens are missing one electron from their outer shell, and will react violently with the alkali metals to form salts.

Noble gases
These elements have a complete outer shell of electrons and do not react with other elements.

Transition metals
The elements in this block have more than one partially filled electron shell, giving them interesting chemical properties.



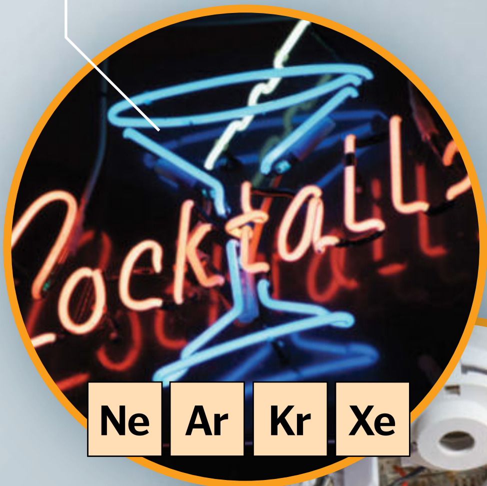
"The puzzle was finally solved by Dmitri Mendeleev in 1869"

Everyday elements

Look around and you'll discover dozens of different elements

Gas-discharge lamps

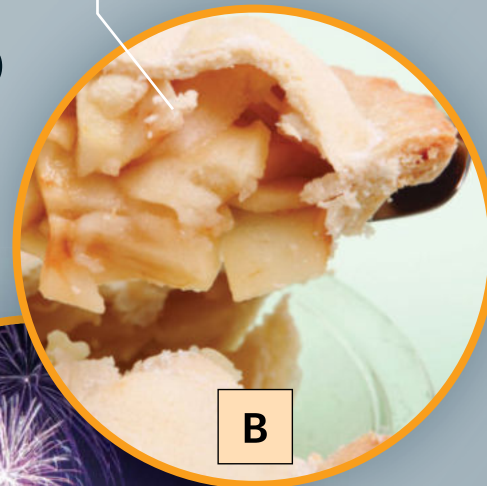
These lamps typically contain neon, argon, krypton, or xenon, which are noble gases. When an electric current is passed through the gases, they become excited, and when they drop back down to a normal energy level, they release photons of visible light.



Ne Ar Kr Xe

Heat resistant glass

Borosilicate glass, which is found in the kitchen and in the lab, contains at least five per cent boron oxide. Boron has a high melting point, which helps the glass to resist thermal shock, going from hot to cold and back again without shattering.



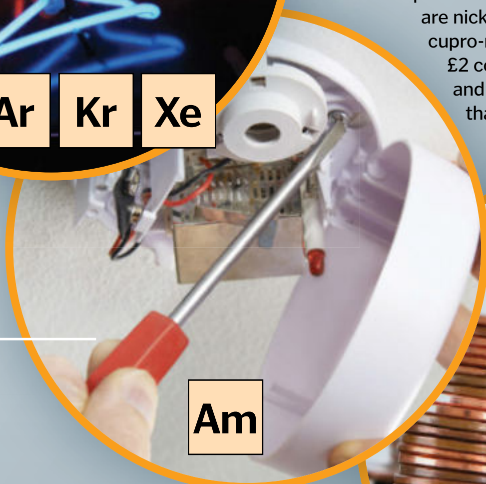
B

Coins

In the UK, 1p and 2p coins are made from copper-plated steel (iron and carbon), 5p and 10p coins are nickel-plated steel, 20p and 50p coins are cupro-nickel (copper and nickel), and £1 and £2 coins are nickel-brass (copper, nickel and zinc). These elements are cheaper than gold or silver, and durable too.

Fe C

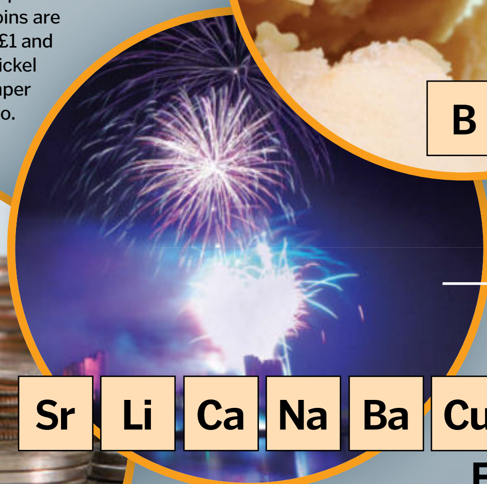
Cu Ni Zn



Am

Smoke detectors

Many smoke detectors contain small amounts of americium. This radioactive element releases alpha particles, which 'knock' electrons away from gases in the air and towards a positively charged plate in the smoke detector, generating a current. When smoke gets in the way, the current stops and the alarm sounds.



Sr Li Ca Na Ba Cu

Fireworks

The colours of fireworks are produced using various combinations of elements, which burn with different coloured flames. Strontium and lithium salts burn red and calcium salts burn orange, while sodium salts burn yellow, barium salts green, and copper salts blue. Purple can be made by mixing strontium and copper.

Phone ingredients

The shiny metal, glass and plastic exteriors of smartphones can contain lots of different elements, including aluminium, magnesium, carbon, and oxygen, but this is just the tip of the iceberg; the circuitry, battery, cameras and speakers contain dozens more. Silicon chips coated with antimony and arsenic sit beside batteries containing lithium and cobalt, and the features that we take for granted, like colour screens, are made possible by rare Earth metals like terbium and europium. Finding uses for all of these elements is a real achievement, but as demand for electronics soars, our limited resources could start to run out.

In Sn O

Indium tin oxide film

Three elements – indium, tin and oxygen – make up the conductive film inside touch screens.

Al Si O K

Aluminosilicate glass

This tough glass is made from a mixture of aluminium, silicon, oxygen and potassium.

Li Co O

Lithium ion battery

The positive electrode contains lithium, cobalt and oxygen, and the negative electrode is made from carbon.

La Gd Dy

Rare earth circuitry

Smartphone circuitry contains rare earth metals like lanthanum, gadolinium and dysprosium.

Cu Ag Au Ta

Precious metal wiring

Copper, silver, gold and tantalum are used in micro-electrical components and wiring.

YOU ARE MADE OF STARDUST

The elements that make up our bodies were forged inside ancient stars

Hydrogen is the smallest element, and formed in vast quantities after the Big Bang, along with a less plentiful supply of helium, and even smaller amounts of lithium and beryllium. But making the heavier elements required more energy. Hydrogen and helium gas clumped together to form clouds, and these clouds collapsed to form stars with enough heat and pressure to trigger nuclear fusion; inside the stars, the nuclei of hydrogen atoms slammed together, fusing to form helium.

As the stars aged, the helium atoms started to create even heavier elements, including carbon, nitrogen and oxygen. Depending on the mass of the star, this process sometimes continued, producing the nuclei of most of the elements up to number 26, iron. After this critical point, fusion reactions stop releasing energy. When stars run out of useable fuel, they collapse, kicking layers of gas and heavy elements out into space.

For the most massive stars, this process involves a powerful explosion called a supernova, which provides enough energy to make the elements that are heavier than iron. The remnants of these old exploded stars mix with yet more hydrogen gas and go on to make more star systems, like our own Sun and planets, providing us with the range of elements we have on Earth today.

"The remnants of old exploded stars go on to make more star systems"

65% O OXYGEN

Oxygen makes up over half of our body weight. It is one of the key components of water, and is one of the three essential elements needed to make biological molecules like fat and protein.

18.5% C CARBON

Carbon can make four bonds to other elements, making it the perfect scaffolding for building large, complex molecules. It is an essential component of fats, proteins, sugars and DNA.

9.5% H HYDROGEN

Hydrogen is the third element found in all biological molecules. There are actually more hydrogen atoms in the body than carbon or oxygen, but they are much lighter.

3.2% N NITROGEN

Oxygen, carbon and hydrogen make up the core of all biological molecules, but lots of other elements are used in smaller amounts. Nitrogen is found in both DNA and protein.

1.5% Ca CALCIUM

Calcium is found in bones and teeth, and also plays an important role in signalling between cells, in muscle and nerve function, and in blood clotting.

P 1% PHOSPHORUS

Phosphorus, like calcium, helps to provide strength to bones and teeth. It is also involved in energy use, and is a vital component in DNA, helping to hold the whole structure together.

0.4% POTASSIUM K

Potassium ions are found dissolved inside cells and in body fluids. They carry an electric charge, and are used by nerve cells and muscle cells in the transmission of electrical impulses.

S 0.3% SULPHUR

Sulphur is found in some of the building blocks of protein. It can make strong bonds to other sulphur atoms, helping to fix proteins into their 3D shapes.

Na 0.2% SODIUM

Sodium is another electrolyte that carries charge inside the body. Along with potassium and chlorine, it is one of the key elements responsible for normal nerve and muscle function.

0.4% AND THE REST

There are many other elements in the human body, including chlorine, magnesium, manganese, iron, fluorine, cobalt, copper, zinc, selenium, molybdenum, iodine, lithium, and aluminium.

Cl	Mg	Mn	Fe	F	Co	
Cu	Zn	Se	Mo	I	Li	Al

Inside a blood vessel

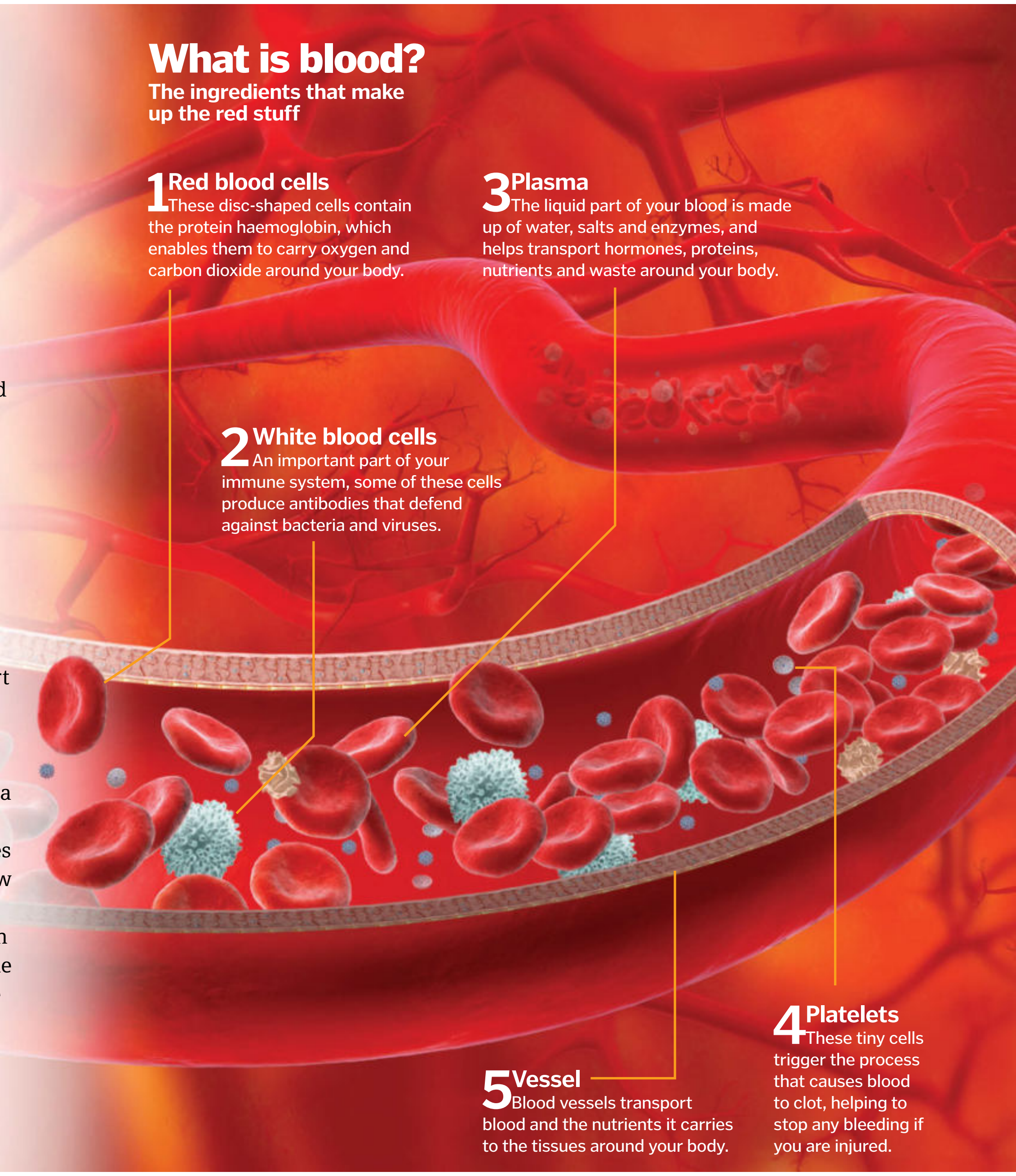
Discover what happens every time your heart beats

Inside your body there is a vast network of blood vessels that, if laid end to end, could easily wrap twice around the Earth. They are an important part of your circulatory system, carrying the equivalent of more than 14,000 litres of blood around your body every day to transport vital nutrients to where they are needed.

There are five main types of blood vessel. In general, arteries carry oxygenated blood away from the heart and have special elastic fibres in their walls to help squeeze it along when the heart muscle relaxes. The arteries then branch off into arterioles, which pass the blood into the capillaries, tiny blood vessels that transport nutrients from the blood into the body's tissues via their very thin walls.

As well as nourishing the tissue cells, capillaries also remove their waste products, passing the now deoxygenated blood on to the venules. These vessels drain the blood into the veins, which, with the help of valves that stop the blood flowing in the reverse direction, carry it back to the heart where it can pick up more oxygen.

In contrast to the other blood vessels in the body, the pulmonary artery takes deoxygenated blood from the heart to the lungs, where it is oxygenated and carried back to the heart via the pulmonary veins.



What is blood?

The ingredients that make up the red stuff

1 Red blood cells
These disc-shaped cells contain the protein haemoglobin, which enables them to carry oxygen and carbon dioxide around your body.

2 White blood cells
An important part of your immune system, some of these cells produce antibodies that defend against bacteria and viruses.

3 Plasma
The liquid part of your blood is made up of water, salts and enzymes, and helps transport hormones, proteins, nutrients and waste around your body.

4 Platelets
These tiny cells trigger the process that causes blood to clot, helping to stop any bleeding if you are injured.

5 Vessel
Blood vessels transport blood and the nutrients it carries to the tissues around your body.

What is hyperventilation?

Find out why it's not always best to reach for the paper bag

Also known as over-breathing, hyperventilation is a common side effect of a panic attack or strong feelings of anxiety. When you feel breathless, you breathe more rapidly in an attempt to get more oxygen into your system. However, rather than increasing the levels of oxygen in your blood, this instead causes the carbon dioxide levels to decrease. As a result, the pH of your blood becomes more alkaline, causing the red blood cells to cling on to their oxygen instead of passing it on to the tissue cells as they would normally. This simply exacerbates the problem, causing you to try to breathe in more oxygen and lowering your carbon dioxide levels further.

One way to stop the vicious cycle is to breathe into a paper bag, forcing you to re-breathe some of your exhaled carbon dioxide. However, this will only work if the hyperventilation was brought on by anxiety or a panic attack. Over-breathing can also be caused by asthma, infections, bleeding or heart attacks, and in these cases, increased levels of carbon dioxide are dangerous. Therefore, the best course of treatment is to try to stay calm and slow your breathing, and seek medical help if the problem persists.

Breathing into a paper bag can be a dangerous way to treat hyperventilation

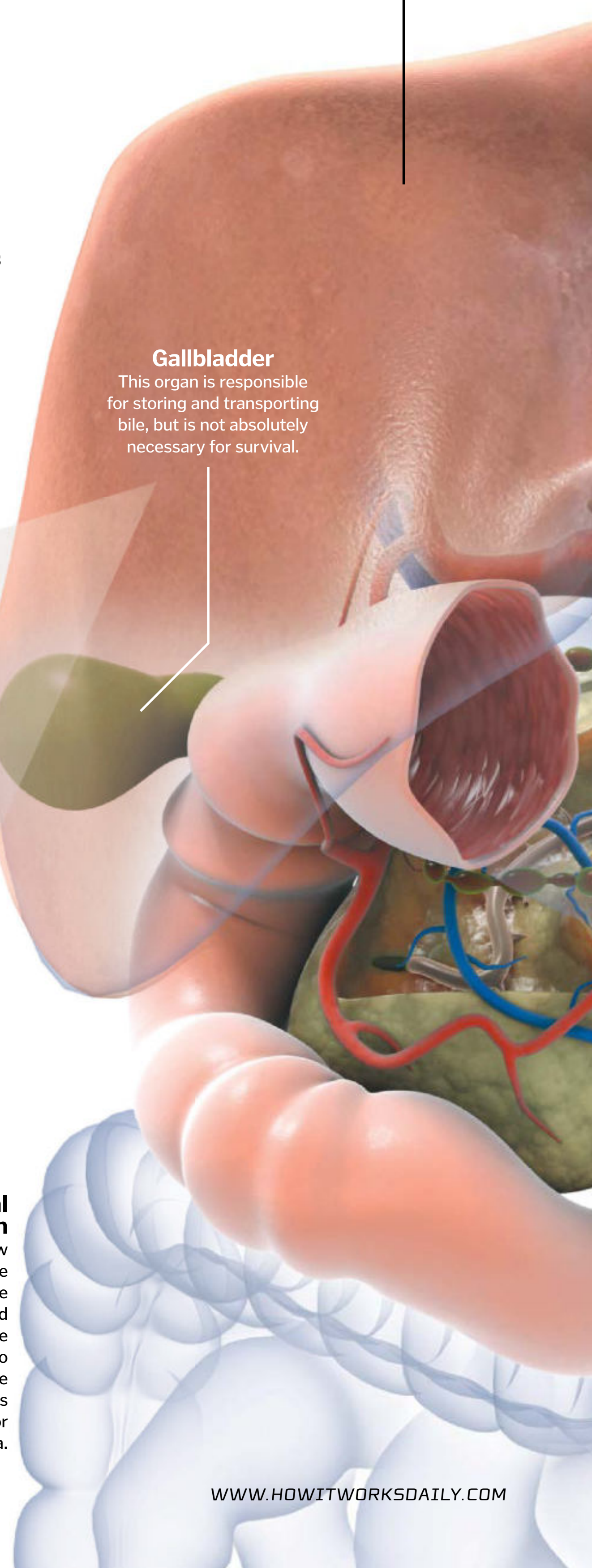
INSIDE THE LIVER AND PANCREAS

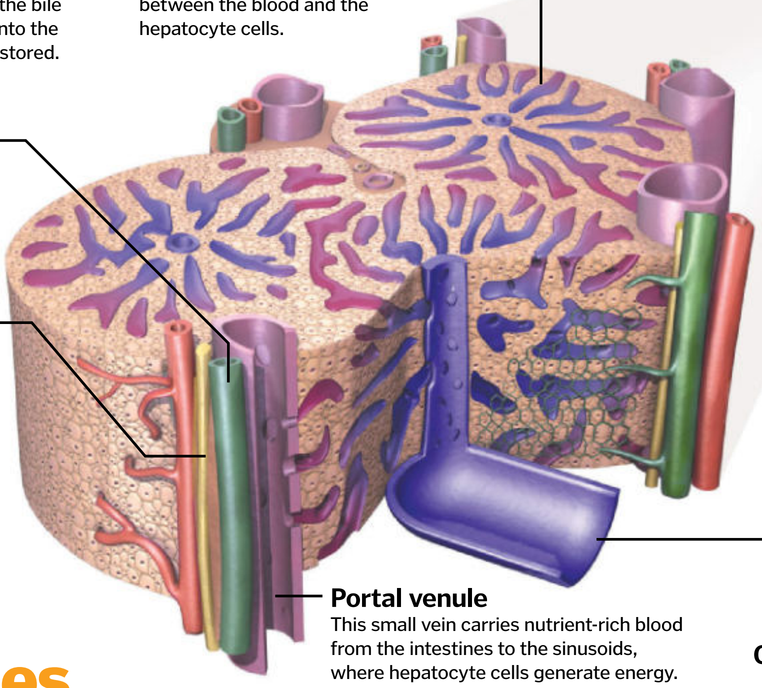
How do these vital organs work together to digest food?

Weighing more than a bag of sugar, the liver is the largest of all the internal organs. It's located mostly in the right side of your abdominal cavity and is capable of holding roughly ten per cent of your body's total blood volume, with around a quarter of your blood supply passing through it every minute.

The liver has many roles in the body, one of which is producing bile, the substance that breaks up fat molecules to aid digestion. Up to one litre of this greenish-yellow liquid is produced and released every day, containing a combination of salts, water, cholesterol and a pigment called bilirubin. Bile travels from the liver to the gallbladder, where it is stored. When a fat-containing food reaches the duodenum (part of the small intestine), the gallbladder is stimulated to secrete this bile, which travels through the bile duct and reaches the duodenum. Here it breaks down complex fat molecules into smaller, circular globules – a process called emulsification. These globules are smaller and have a larger total surface area, making them easier to digest.

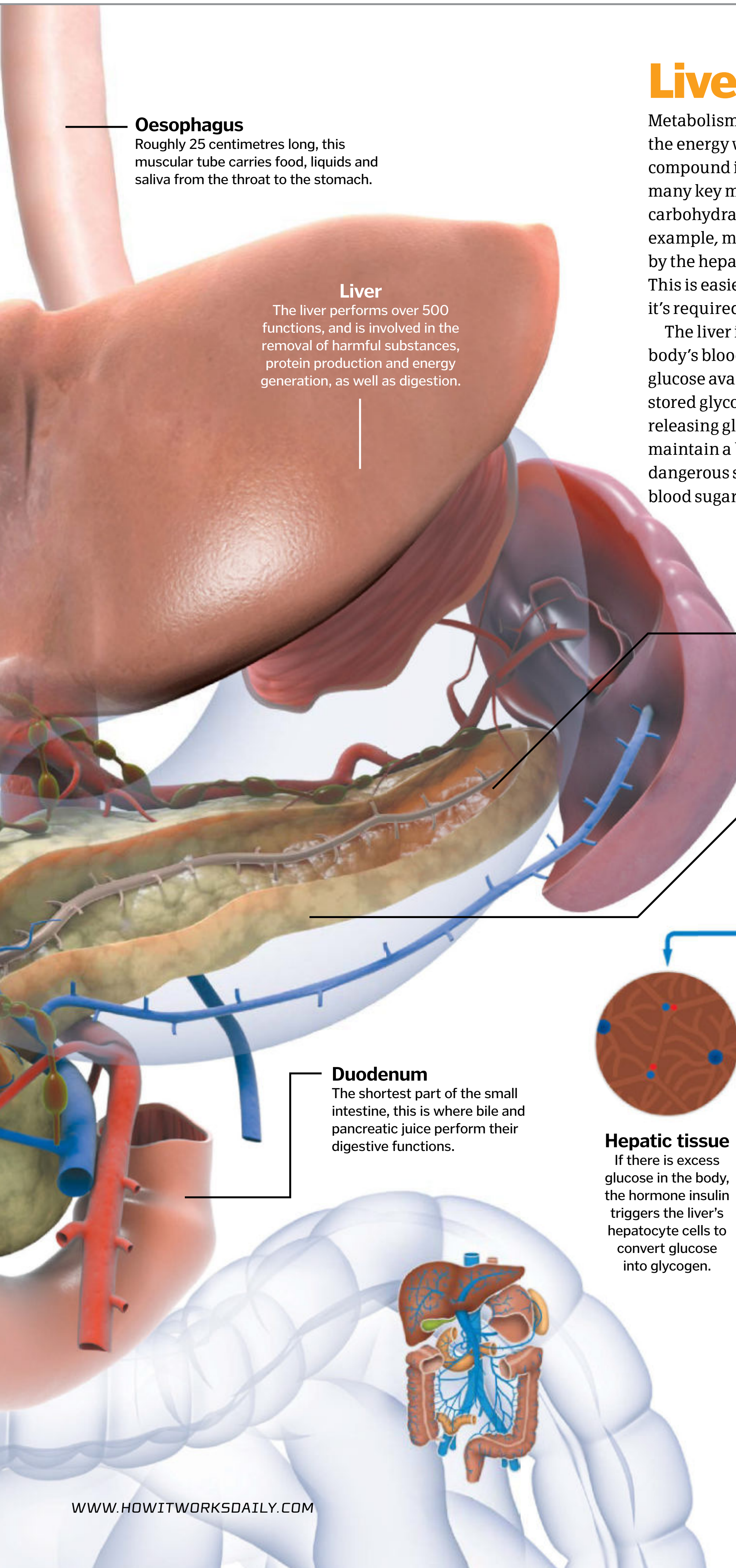
The pancreas also plays a role in digestion, as it produces substances that help to break down food. When the stomach and duodenum are stretched by the presence of a meal, the pancreas is triggered to deliver an assortment of enzymes in a cocktail known as pancreatic juice. An enzyme called amylase breaks down starches, while trypsin digests proteins and lipase works on fatty acids.





Liver lobules

The lobules comprise of rows of hepatocytes (liver cells), bile ducts and blood vessels. Roughly 100,000 of these hexagonal-shaped structures sit within the organ, each consisting of a central vein surrounded by six hepatic portal veins and six hepatic arteries. These blood vessels are connected by sinusoids, which are small tubes joining the central vein to the surrounding veins and arteries. The products from digestion are transported in the blood to the sinusoids, where they can be absorbed into the hepatocytes.



Oesophagus
Roughly 25 centimetres long, this muscular tube carries food, liquids and saliva from the throat to the stomach.

Liver
The liver performs over 500 functions, and is involved in the removal of harmful substances, protein production and energy generation, as well as digestion.

Pancreatic duct
Pancreatic juice is secreted into this duct before passing into the common bile duct, which leads to the duodenum.

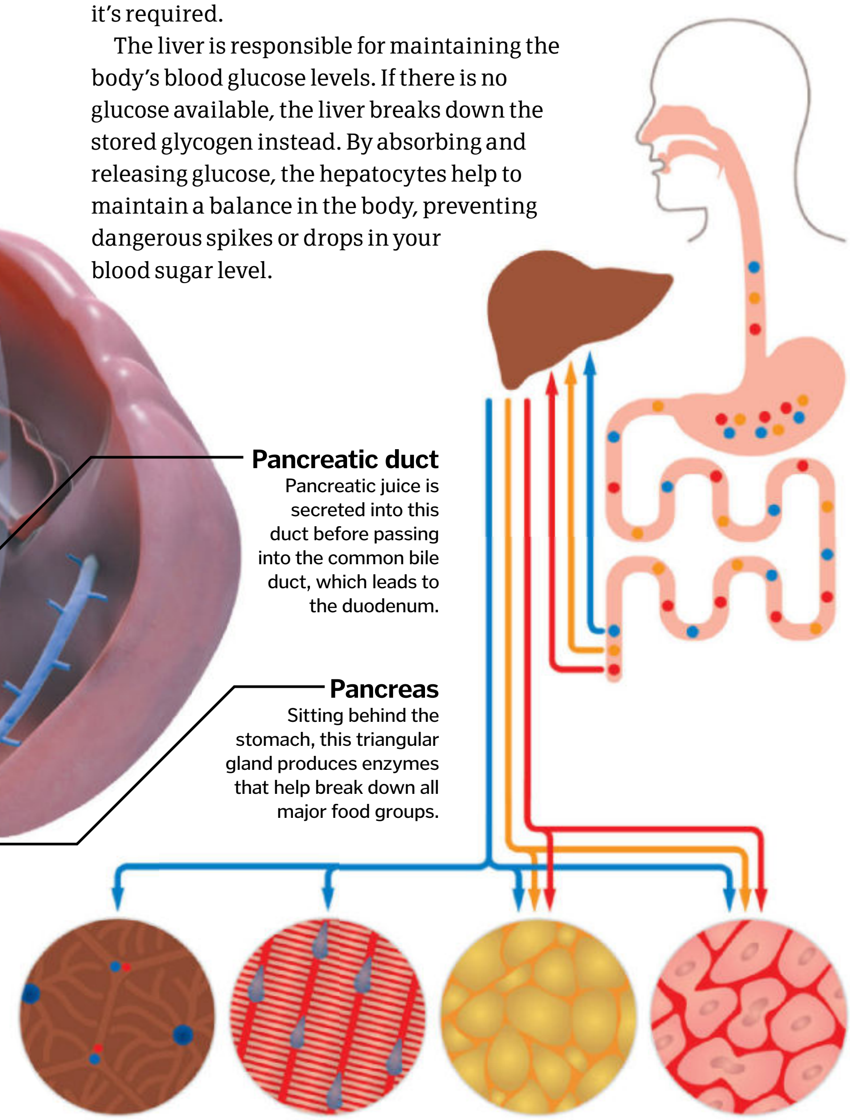
Pancreas
Sitting behind the stomach, this triangular gland produces enzymes that help break down all major food groups.

Duodenum
The shortest part of the small intestine, this is where bile and pancreatic juice perform their digestive functions.

Liver metabolism

Metabolism is more than just the body's way of breaking down food into the energy we need to survive – it's the conversion of one chemical compound into another. In the liver, cells called hepatocytes perform many key metabolic tasks. These cells work to convert proteins, fats and carbohydrates into molecules that the body can use or store. For example, much of the glucose that passes through the liver is absorbed by the hepatocytes, which stockpile it as a larger molecule, glycogen. This is easier to store and can be quickly turned back into glucose when it's required.

The liver is responsible for maintaining the body's blood glucose levels. If there is no glucose available, the liver breaks down the stored glycogen instead. By absorbing and releasing glucose, the hepatocytes help to maintain a balance in the body, preventing dangerous spikes or drops in your blood sugar level.



Hepatic tissue
If there is excess glucose in the body, the hormone insulin triggers the liver's hepatocyte cells to convert glucose into glycogen.

Muscle fibres
Both the liver's muscle cells and hepatic cells are able to store glycogen within them.

Adipose cells
These cells store excess fatty acids in the form of long-chain fat molecules.

Cellular growth and repair
A process called anabolism builds amino acids into proteins, which can then be used to construct cells and produce enzymes.

"Around a quarter of your blood supply passes through your liver every minute."

What is a mirage?

Find out how thirsty explorers are fooled by a trick of the light

Stumbling through the scorching desert, you spot something up ahead. A shimmering pool of water appears in the middle of the vast emptiness, but as you scramble towards it for a much-needed drink, it suddenly vanishes into thin air. In actual fact, the pool was an optical illusion created by a cruel trick of the light.

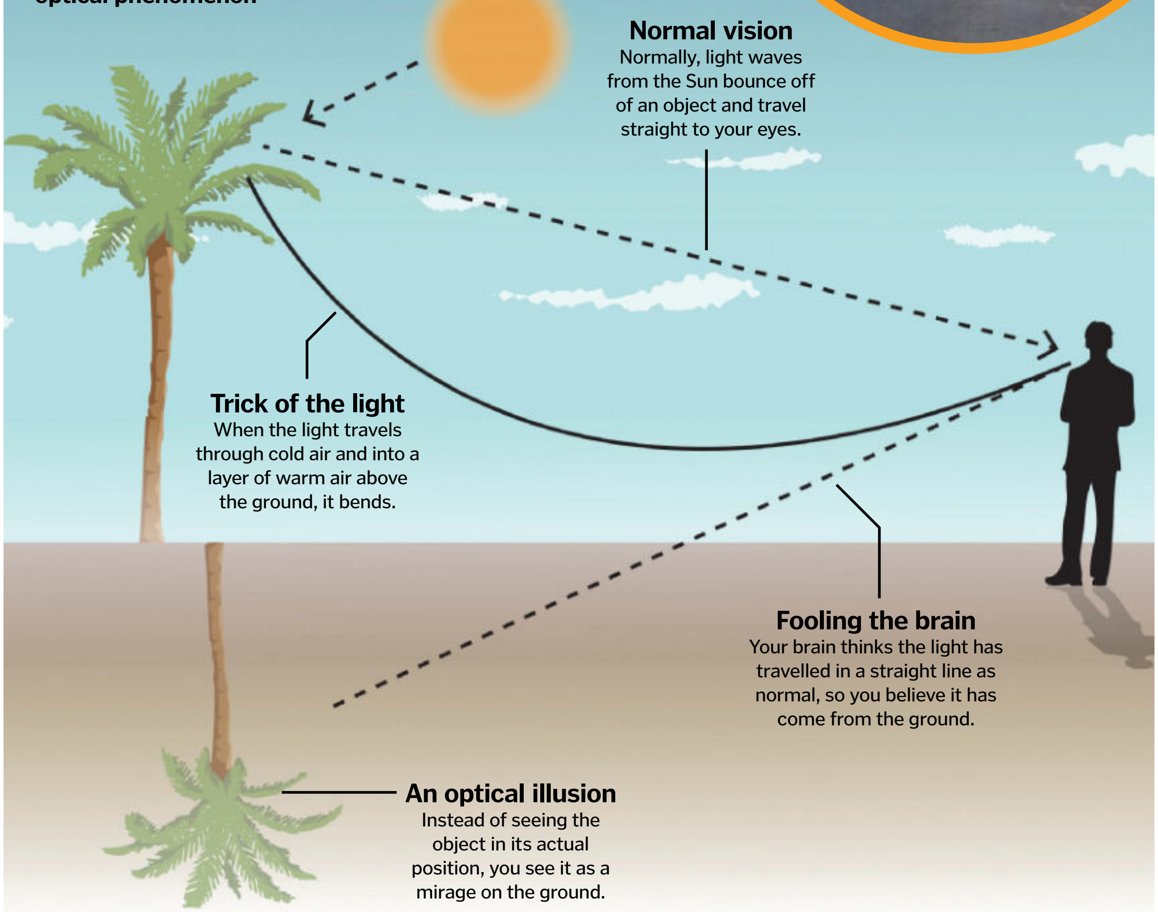
Mirages such as this occur when the ground warms up the layer of air above it. They are common above roads and deserts, because tarmac and sand absorb a lot of heat, some of which is transferred into the surrounding air. As the layer of warmer air is less dense than the cold air above it, the change in density causes light to refract, or bend, as it travels through it.

However, your brain isn't aware that this has happened, so it assumes the light has travelled in a straight line from the ground. The pool you think you see is actually blue sky refracted from up above, and there is no thirst-quenching water after all.

An open road on a hot day can create a shimmering mirage up ahead

Conjuring images

The science behind this optical phenomenon



How does moisturiser work?

The clever creams that keep your skin soft and smooth

The job of moisturisers is to trap and replenish the moisture that evaporates from the upper epidermis layer of your skin. They fall into three main categories, but most products are made of a combination of ingredients from some or all of these. The most basic are occlusives such as Vaseline, which contain molecules that repel water to create a barrier over the skin that stops evaporation.

The second kind, known as emollients, are absorbed into the skin instead of sitting on top of it. They fill the gaps left in the epidermis when fatty proteins that join together dead skin cells are broken down by a lack of moisture in the air. By plugging these gaps they stop any moisture from evaporating and smooth the skin to make it soft and supple.

The third type of moisturisers – humectants – absorb moisture from the air and dermis layer of the skin to hold it in the epidermis. They also stimulate the body's natural production of ceremides – fat molecules that prevent water evaporating from the skin.

Moisturisers help to stop water leaving the epidermis, the process by which skin dries out

60 SECOND SCIENCE

Archimedes' principle

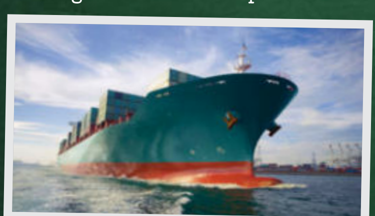
FIND OUT WHY BOATS FLOAT ON WATER

BACKGROUND

According to the Roman author Vitruvius, King Hiero II of Syracuse commissioned a goldsmith to make him a crown, but upon receiving it, was not convinced it was pure gold. He asked Archimedes to determine whether he had been ripped off. Archimedes couldn't melt the crown or damage it, and chemical analysis had not been invented. He had to find alternative means of determining its purity. The experiments that followed were the basis of our understanding of density and buoyancy.

IN BRIEF

The 'eureka' moment reportedly came while Archimedes was taking a bath. When he climbed in, the water level rose and he realised that the volume of water he displaced must be equal to his body's volume. If he was bigger, more water would spill onto the floor. He also noticed that the water must be pressing up against him to support his weight, otherwise he would sink to the bottom. This force is now called buoyancy, and is due to the fact that fluid pressure increases with depth. The buoyant force counteracts the object's weight, pushing up with an equal force. But if the object is heavier than the volume of water it displaces (meaning it is denser than water), it will sink. Using this logic, Archimedes proved that the king's crown was not pure.

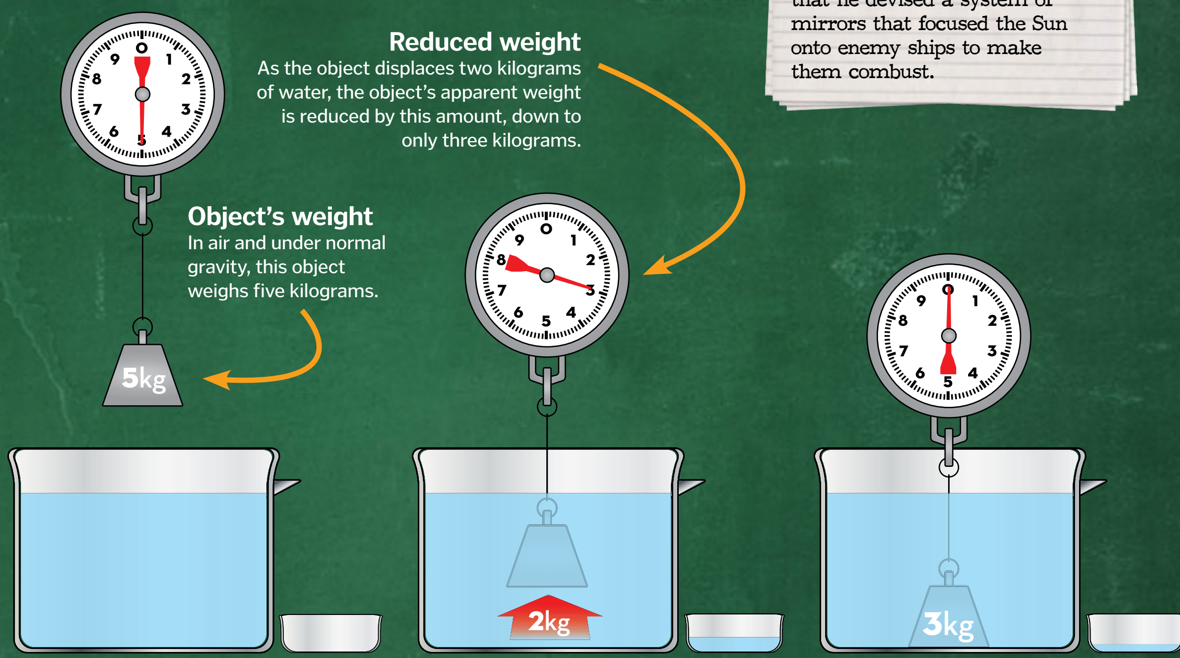


SUMMARY

Fluids exert a buoyant force on objects completely or partially submerged in them, and the size of this force is equal to the weight of the fluid displaced by the object.

The theory in action

See how Archimedes' principle works in this simple experiment



Reduced weight
As the object displaces two kilograms of water, the object's apparent weight is reduced by this amount, down to only three kilograms.

Object's weight
In air and under normal gravity, this object weighs five kilograms.

Buoyant force
Buoyancy counteracts gravity, pushing up with a force equal to the weight of the water that has been displaced.

Volume
The object's volume is equal to the volume of water displaced, a fundamental part of Archimedes' discovery.

Density
This object is denser than the water, so its weight is greater than the weight of the fluid it displaces. This means that it sinks to the bottom.

Archimedes

287 BCE – 212 BCE

Mathematician, astronomer, engineer and inventor, Archimedes was one of the most brilliant minds in ancient Greece. He was famous for his discoveries about buoyancy and density, his work on pulleys and levers, and his contributions to geometry. It is even reported that he devised a system of mirrors that focused the Sun onto enemy ships to make them combust.

WHERE IS ARCHIMEDES' PRINCIPLE USED TODAY?

- IT'S USED TO CALCULATE HOW DEEP A SHIP WILL SINK WHEN IT'S LOADED WITH CARGO, WHICH ALLOWS ENGINEERS TO FIGURE OUT A CONTAINER SHIP'S MAXIMUM LOAD.
- JUST AS ARCHIMEDES REPORTEDLY VERIFIED THE KING'S CROWN, THIS PRINCIPLE CAN STILL BE USED TO ASSESS THE PURITY OF EXPENSIVE ITEMS SUCH AS JEWELLERY.
- HYDROMETERS USE ARCHIMEDES' PRINCIPLE TO MEASURE THE RELATIVE DENSITY OF SPECIFIC LIQUIDS, BY OBSERVING HOW DEEP AN OBJECT SINKS WITHIN THEM.
- BALLAST TANKS IN SUBMARINES USE THIS PRINCIPLE TO ALLOW THE SUB TO STAY AT ANY CHOSEN DEPTH, WITHOUT FLOATING TO THE SURFACE OR SINKING FURTHER.


Overeating can damage your brain's ability to tell you when you're full

What happens when you eat too much?

Learn about the effects of an all-you-can eat buffet

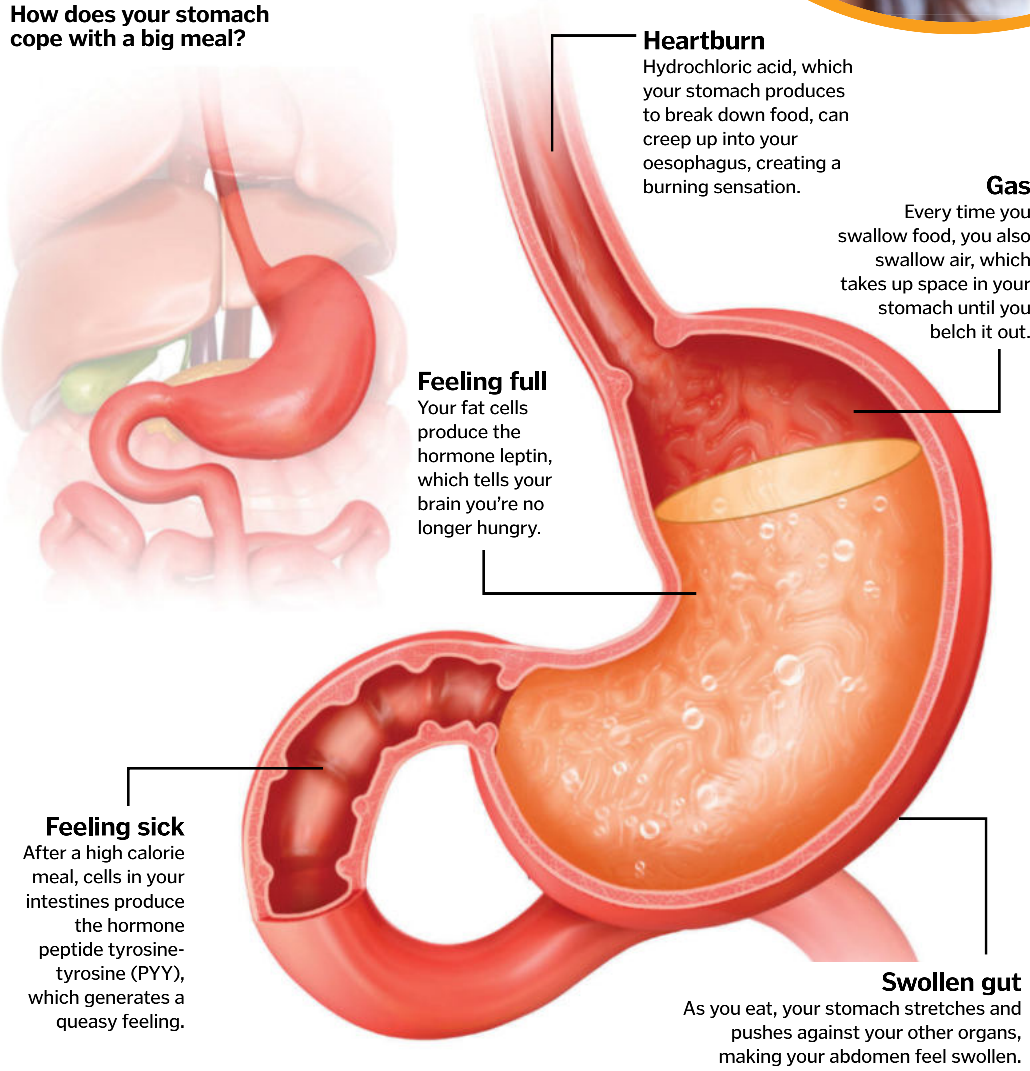
When you've just polished off a plate piled high with food, it can sometimes feel like you're going to explode. Although it is possible for your stomach to rupture after overeating, your gag reflex is likely to kick in long before you reach that point. The average human stomach can handle between one and one-and-a-half litres of food before getting the urge to throw it back up, but can stretch to accommodate four times that much before a rupture occurs.

When you eat a meal that's high in fat, sugar and carbohydrates, your parasympathetic nervous system tells your body to slow down and focus on digesting the food, causing you to feel lethargic. As the food is digested, cells in your pancreas produce the hormone insulin, which in turn leads to an increase in melatonin and serotonin, hormones that makes you feel drowsy as well as happy. You may also struggle to keep your eyes open thanks to a spike in glucose levels from the food you've eaten. This can interfere with the neurons in your brain that normally produce the orexin proteins responsible for keeping you awake and alert.

Your fat cells produce the hormone leptin, which binds with receptors in the brain to tell you that you're no longer hungry. Regularly eating more than your body needs causes your body to produce more of this hormone, as leptin levels are directly related to the amount of body fat a person has. In such cases, people may build up a resistance to leptin, which disrupts the brain's ability to recognise when you're full, leading you to overeat and put on weight.

Ready to pop

How does your stomach cope with a big meal?



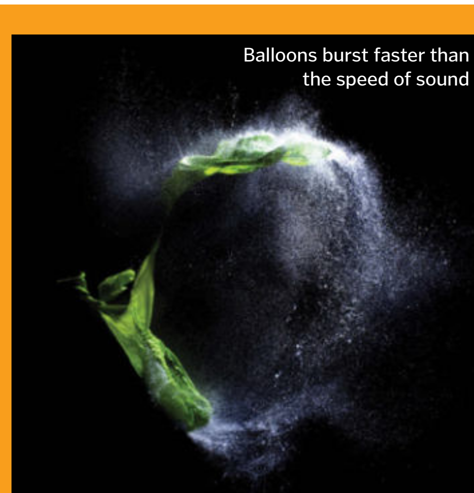
Why do balloons go bang?

Discover how popping a balloon creates a sonic boom

When you stick a pin in an inflated balloon, all of the tension of the stretched rubber is transferred to the edges of the pierced hole. As this force is too much for the hole to take, it quickly expands until the entire balloon has been ripped apart.

This happens faster than the speed of sound, so as the high pressure air inside the balloon is released, it expands to create a pressure wave that breaks the sound barrier. Our ears pick up this wave as sound, and so the noise you hear is actually a sonic boom, similar to that created by a supersonic aircraft flying across the sky.

If you want to avoid making everyone in the vicinity jump out of their skin, then simply place a piece of sticky tape on the balloon and pierce the hole through that. The tape is strong enough to resist the force from the rubber as it tries to rip apart the hole, so the air will leak out slowly and not produce a bang.


Balloons burst faster than the speed of sound

DID YOU KNOW? *With three times more gas than beer, it's estimated that one bottle of champagne contains 50 million bubbles!*

How champagne is made

Raise a glass and read on to learn the origins of this celebration tipple


The lengthy and laborious process for making champagne explains the lofty price tag

A glass of bubbly is a lavish treat for most of us, or for the rich and famous it can be used to bathe in (Marilyn Monroe did it, apparently!). But what sets it apart from regular wine? It's the lengthy double fermentation process that elevates champagne into the realms of luxury. True champagne only comes from grapes grown in the Champagne region in France; the rest are sparkling wines. It is usually made with Pinot Noir grapes, which must be picked and handled carefully to avoid the dark colour of their skins staining the pale champagne.

The beginnings of a bottle start with a blend of still wine, or 'cuvée', to make the base of the champagne. The grapes are pressed and the juice is left to ferment in a barrel – this is the primary fermentation. Then a 'liqueur de tirage' is added, made of sugar, yeast and wine. Once it is bottled and a temporary seal added, the secondary fermentation happens and yeast starts to turn the sugar into alcohol, producing bubbles of carbon dioxide for that quintessential champagne fizz.

Bottles are stored facing downwards so that the yeast cells gather at the neck, and then they are riddled (tilted up and down) every so often to prevent sediment from sticking to the glass. After a sufficient time, the bottles are plunged into freezing brine. This turns the yeast sediment to ice, which can then be removed from the bottle, a process known as disgorgement. The last step before stopping with the traditional wire-caged cork is to top the bottle up with a 'liqueur d'expédition' – a mixture of still wine and sugar – which can sweeten the champagne's flavour. It's a lot more work than popping the cork!

From grape to glass

The journey from the vineyards of France to the pop of the cork

1 On the vines

Grapes are selected to make the cuvée – a blend of still wine. Pinot Noir, Pinot Meunier and Chardonnay grapes is usually used, with each grape adding its own flavours and aromas to the finished product.

2 Primary fermentation

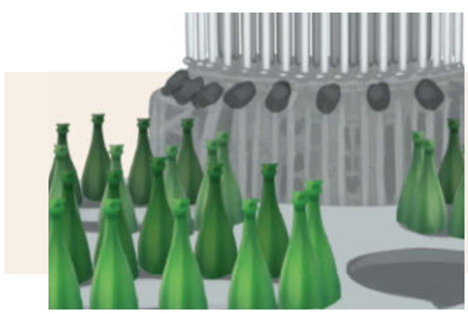
The grapes are loaded into the press, and the mechanical lid is lowered and raised repeatedly. The juice that runs off, known as cuvée, is poured into bottles or casks to ferment. This forms the base of the champagne.

3 Secondary fermentation

A sugar and yeast mixture called liqueur de tirage is added and the bottle is sealed. It is then left for the bubbles and flavour to develop. Pressure builds up in the bottle until it is equal to that of the air inside a tyre!

4 Aging and riddling

By law, champagne must be aged for at least 15 months, although luxury versions may be aged for two years or more. The bottles are tilted by one eighth of a turn each day, a process known as riddling.



5 Disgorgement

The neck of the bottle is dipped into freezing liquid, creating a pellet of ice. This is carefully removed, taking any sediment with it, and then extra sugar and still wine are added to enhance the champagne's flavour.

6 Corking and shipping

The bottles are then sealed with a long, fat cork that is printed with the name of the winery, and then secured with a wire cage. The champagne is stored in a cellar, ready to be popped on a special occasion!

HIGH-TECH TOYS

Discover the tech that brings the latest must-have gadgets to life

ADOPT A STAR WARS DROID

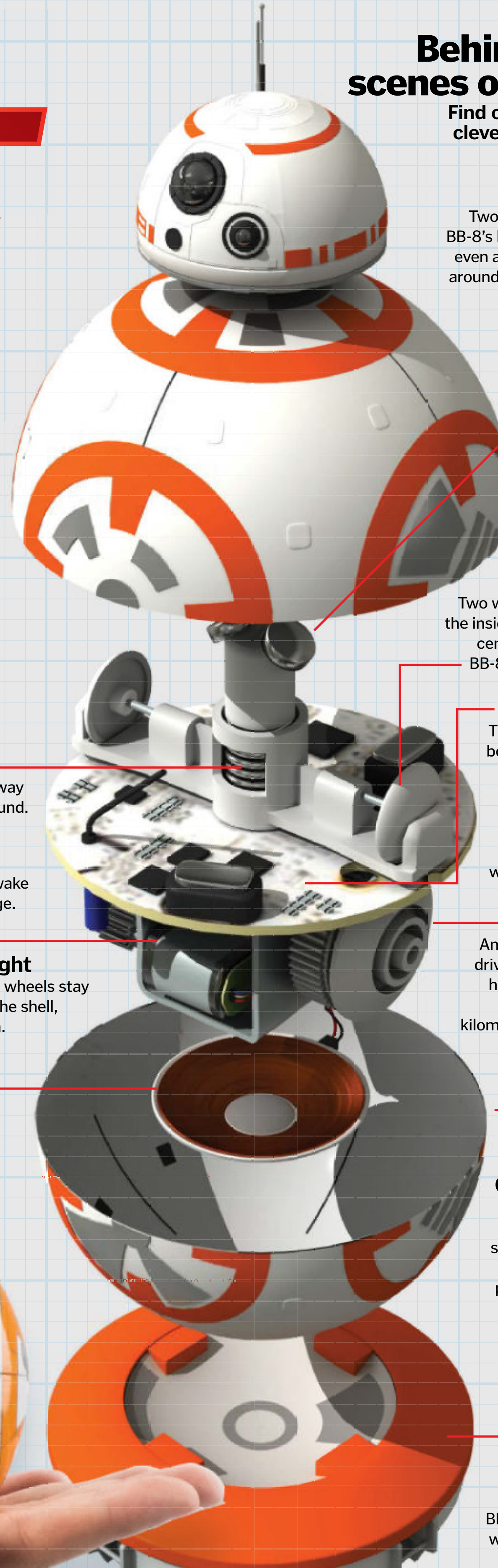
Let The Force Awakens' cutest star patrol your home

Price: £129.99 / $149.99
Web: www.sphero.com

Of the many toys inspired by the new *Star Wars* movie, Sphero's mini replica of the BB-8 droid is certainly the most adorable. This cute cousin of R2-D2 connects to an accompanying app via Bluetooth, so you can control it with your smart device. You can design a route for BB-8 to patrol autonomously or give it voice commands to follow. For example, saying "it's a trap" will cause BB-8 to panic and roll away. The more you play, the more BB-8's actions and attitudes will evolve. Eventually it will recognise your voice, respond to your commands in different ways and become your loyal companion. What's more, you can use BB-8 to send and view holographic messages for a truly futuristic experience.

Behind the scenes of BB-8

Find out how this clever droid rolls



Create your own *Star Wars* adventures with BB-8 by your side

i-Que can answer your questions and challenge you to a dance-off

LEARN FROM A ROBOT KNOW-IT-ALL

Get your curious questions answered by an android pal

Price: £64.99 / $99.99
Web: www.ique-robot.co.uk

If your friends and family are getting tired of answering your questions about anything and everything, then this little robot companion will give them a break. When paired with your internet-enabled smart device, i-Que can provide answers to even the most difficult questions, giving our Brain Dump experts a run for their money. Thanks to speech-to-text technology, he can understand almost anything you say and you can change the sound of his voice to control how he answers back. i-Que can also help you train your brain by challenging you with trivia questions, brain-teasers and memory games, so you can try to become as clever as him. As well as super smarts, i-Que also has some killer dance moves and a sense of humour, as it can move to music and tell jokes to keep you entertained for hours. We're thinking of employing him to join the **How It Works** team!

The SmartGlider will move in whichever direction you lean

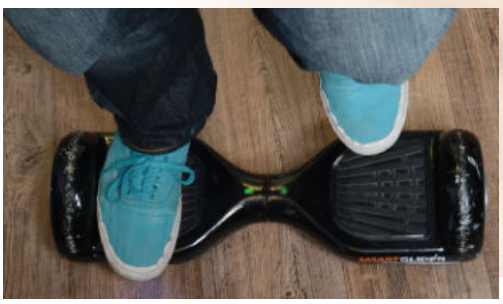
STEP ON A HOVERBOARD

Why walk when you can glide?

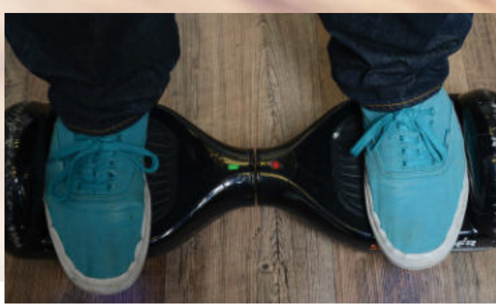
Price: £499.99 (approx $755)
Web: www.futurewheels.com

Okay, so it's not technically a hoverboard, but the self-balancing SmartGlider is the closest you're going to get to Marty McFly's transport of choice for now. Although the two wheels are kept firmly on the ground, you'll feel like you're gliding through the air – once you get the hang of it that is. Placing your feet on the board activates a touch-sensitive motor that drives you forward. Gyroscopes then help keep you balanced and as you shift your weight, they move the board in the corresponding direction. After a bit of practice – the manufacturer recommends an hour's worth – you'll be able to get from A to B with minimal effort. The electronic board takes around one to two hours to fully charge and can travel up to 24 kilometres before the battery runs out. Plus it's easily portable, weighing in at just 13 kilograms.

How to ride a SmartGlider



1 Step on it
Step on with both feet as quickly as possible. This will avoid engaging one motor and not the other, which would cause it to spin or judder.



2 Find your balance
If the board starts beeping or vibrating, it means you're unbalanced. Shimmy around and try to relax, and you'll find that the board does the balancing for you.

3 Get moving
Gently shift your weight in the direction you want to move and the internal gyroscope will send you on your way at speeds of up to 16 kilometres per hour.

FOAM FIREPOWER

Start all-out Nerf warfare with your own fire blaster

Price: £89.99 / $99.99 Web: www.nerf.hasbro.com

Getting your hands on a Nerf gun is the best way to launch a full-scale attack on your friends or family without causing any casualties. While the foam bullets are enough to send your enemy running for cover, you can rest safe in the knowledge that they won't leave any scars – at least not physical ones.

Nerf guns used to require exhausting pump-action, but modern versions are simpler to operate and can hold multiple bullets so you don't have to keep reloading. The Nerf N-Strike Elite Rhino Fire Blaster features two separate barrels, each capable of holding 25 foam darts. Its immense firepower means you can hit targets from up to 27 metres away and motorised firing lets you control the rate of fire. The tripod helps to keep the gun steady, but can be easily removed if you prefer to stalk your target.

Take aim and fire 50 bullets in one session with the Rhino Fire Blaster

How does a Nerf gun fire?

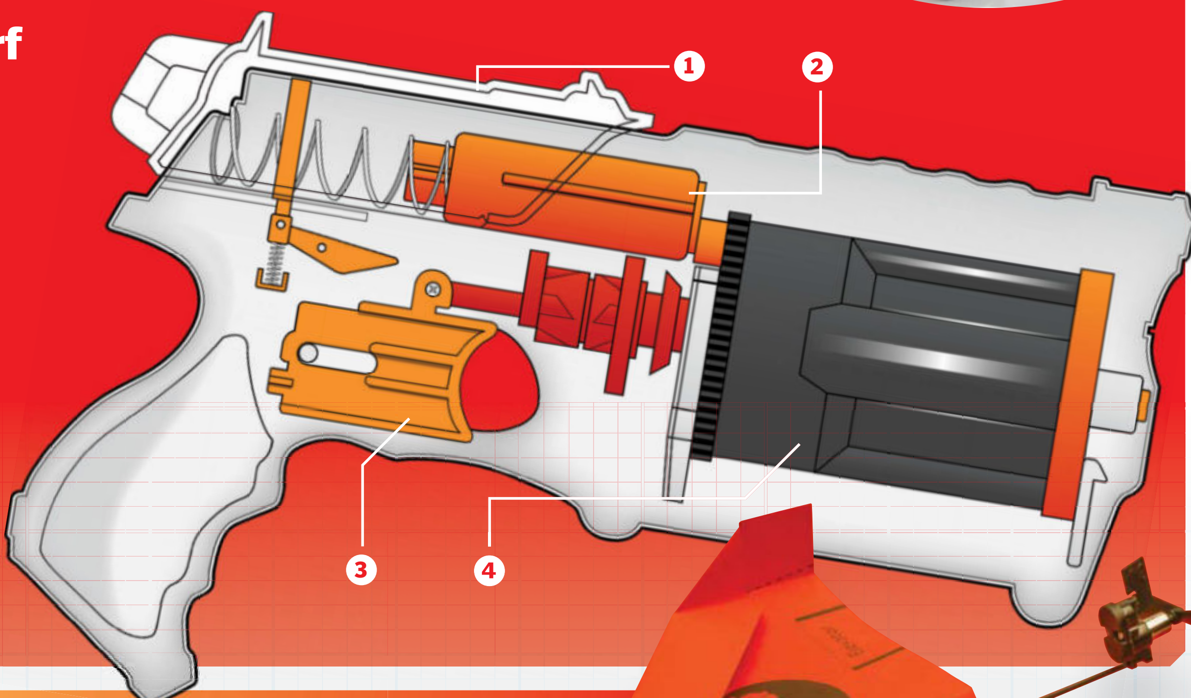
Find out what happens when you pull the trigger

1 Pull the piston
When you pull back the piston on the top of the gun, it compresses the spring.

2 Fill with air
The spring pulls back the plunger, sucking air into the main chamber.

3 Pull the trigger
When you pull the trigger, the piston is released and the spring expands again.

4 Fire some foam
The plunger is pushed forward, forcing air from the chamber into the barrel and propelling the foam bullet forward.

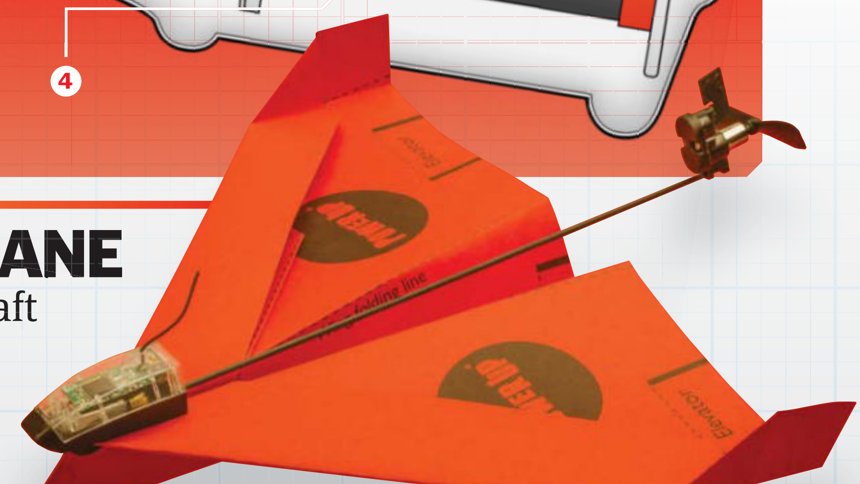


UPGRADE YOUR PAPER PLANE

Add smartphone control to your origami aircraft

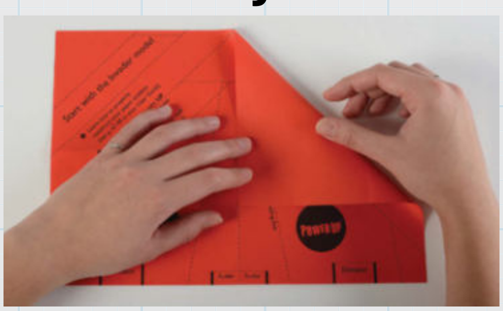
Price: £39.99 / $49.99 Web: www.poweruptoys.com

That's right, even the humble paper aeroplane has gone high-tech! Power Up 3.0 lets you fit an electric motor and rudder to your folded creation, so you can steer it using a free mobile app. The kit also comes with several templates to help you get folding, but here's our favourite configuration…



Tilting your smartphone lets you steer the paper plane left or right

How to fold your PowerUp 3.0



1 Fold in one corner
Take an A4 piece of paper or card and create a crease down the middle. Then fold one corner into the middle so that it lines up with the crease.

2 Fold the other corner
Repeat step 1 with the other corner so that they meet along the middle crease, forming the tip of your plane. Press down the folded edges so they stay in place.

3 Reinforce the body
Fold both of the triangles you just created in half, and then in half again, creating reinforced edges for the wings of your plane.

What's under the hood?

Find out where the Baja 5B gets its immense power from

REMOTE-CONTROL CAR 2.0

This vehicle guzzles petrol like the real thing

Price: £969.99 (approx $1,460) Web: www.hpiracing.com

Remote-controlled cars don't get much more powerful than the Baja 5B with D-Box 2. This large-scale buggy weighs a hefty ten kilograms and is roughly the size of a small dog, so it will certainly give your pets a fright. You can forget about chargers too, as the Baja 5B runs on petrol. The resulting fumes mean it's strictly for outdoor use, but the large rubber tyres are designed to tackle all sorts of off-road terrain.

Perfect for racing enthusiasts, this RC can reach top speeds of over 48 kilometres per hour and features quick acceleration, so you'll be sure to leave your opponents in a cloud of dust. If things get really competitive, the heavy-duty chassis will help the car withstand more than a few knocks and bumps, and the 2.4GHz radio system promises to ensure you're always in control.

ADD SOME AI TO YOUR RACING

Battle friends or robots with a smart racing game

Price: £149.99 / $149.99
Web: www.anki.com

Track-based racing games are making a comeback thanks to the latest technological advancements, and Anki Overdrive is one of the new players on the starting grid. The kit includes a series of track pieces that can be snapped together with magnets to create eight different layouts. The cars wirelessly connect to your smart device and a free app lets you control the acceleration, but they can navigate the track by themselves. Each vehicle has an onboard computer and a camera that scans the track 500 times per second to identify its position and anticipate corners or opponents. Up to four players can race at once, or you can battle Anki's artificially intelligent Commanders instead. You can even fire virtual weapons to slow down your opponent, like a futuristic Mario Kart race.

Anki Overdrive combines physical track racing with app-controlled game play

4 Taking shape
Refold the paper along the crease you made in step 1, making sure the reinforced edges from step 3 are on the inside of the fold. Press down the fold.

5 Fold the wings
Fold the paper back on either side of the middle fold to create a gulley in the centre. Fold the tips of the wings upward to make the plane more aerodynamic.

6 Attach the motor
Slide the PowerUp 3.0 motor into the centre gulley, clipping the engine onto the front of the plane so that the propeller is at the back. You're ready for take-off!

What makes smart bulbs so clever?

How one bulb can produce a whole rainbow of colours

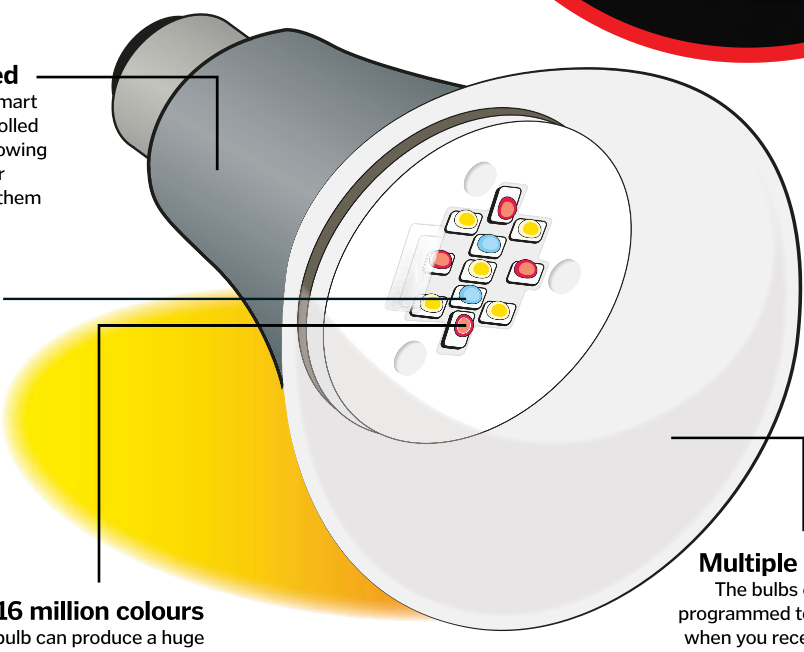
Smart lighting is growing in popularity, offering a quick and inexpensive way of customising a home. Most smart lighting systems are fitted with light emitting diode (LED) bulbs. When you connect an LED to a source of electricity, the current flows through the diode and excites the electrons within it, forcing them to release photons of light.

Philips Hue smart bulbs contain a special semiconductor material that only partially conducts current, and are designed so that the flow of current running through the LEDs can be varied. A range of colours can shine out of the bulb, depending on the strength of the current.

Smart lighting is more than just an aesthetic gadget; it offers a number of practical benefits too. It's highly efficient, as it allows you to control exactly when a light should be on or off. Also, if you leave the house in a rush and forget to turn a light off, you can use the app on your smartphone to switch it off remotely.

Smart bulbs can be controlled remotely from a smartphone

The Philips Hue smart bulb



App-controlled
A set of up to 50 smart bulbs can be controlled by a single app, allowing you to change their colour and switch them on or off remotely.

11 LEDs
The Philips Hue has five yellow, four red and two blue LEDs, giving each bulb a maximum output of 600 lumens.

16 million colours
This smart bulb can produce a huge range of different colours, and offers an abundance of alternative tones.

Multiple uses
The bulbs can be programmed to flash when you receive an email, or even to wake you up in the morning.

How green roofs work

Learn how this layered system grows plants on buildings

By combining layers of waterproofing, drainage and soil, a green roof supports plant life. Each of the six to eight layers has a specific function. First, there's the foundation layer known as roof decking. This is generally made from plywood, concrete or metal, and it shields against the elements as well as providing structural support.

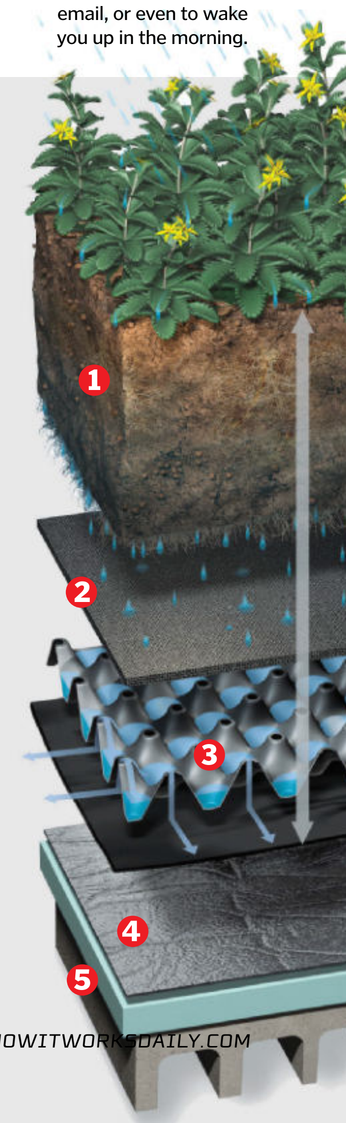
On top of this sits a waterproof membrane and a drainage layer to get rid of excess rainwater. This is topped with a filter fabric that stops the drainage from becoming blocked. The final layer is comprised of plants and their growing medium. This layer absorbs rainwater, providing the plants with a steady supply.

'Living' roofs reduce household bills by providing insulation, keeping the building warm in the winter and cool in the summer. They are also a refuge for wildlife in urban areas.

Even a partially converted roof can benefit the environment and reduce energy bills

Green roofs layer by layer

The typical structure of an eco-friendly rooftop



1 Growing medium
A lightweight, synthetic mix is preferred to standard soil, ensuring that no unnecessary strain is put on the roof.

2 Filter fabric
This lets water through but traps small particles, preventing the drainage layer below from getting blocked.

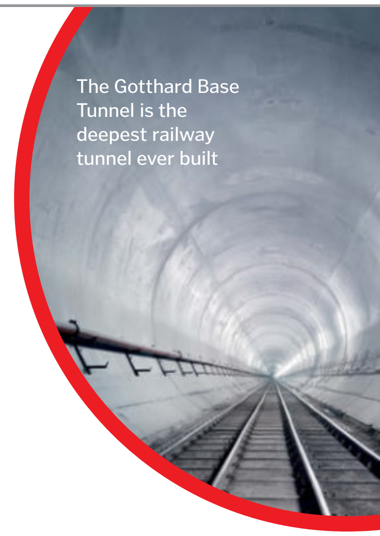
3 Drainage layer
Installing proper drainage is extremely important. This perforated, dimpled plastic sheet makes sure that rainwater can drain off adequately.

4 Waterproof membrane
To stop water seeping into the lower roof layers or the building, a rubbery material similar to pond lining is installed.

5 Roof deck
This layer protects the normal roof from the weight of the tiers above. It is often made of plywood covered with roofing board.

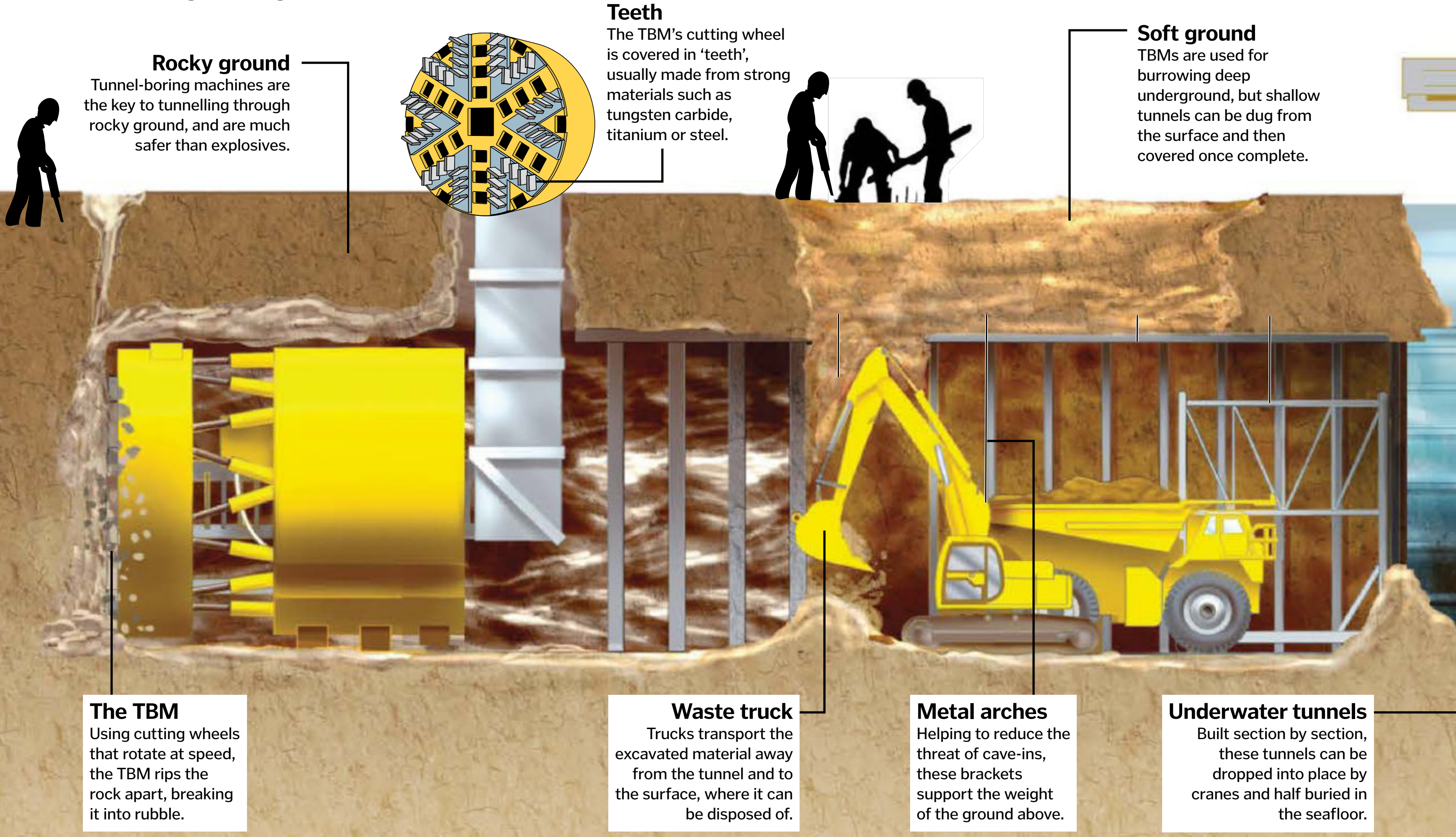
How to tunnel through anything

Discover how tunnel-boring machines tear apart rock and slice through soil


The Gotthard Base Tunnel is the deepest railway tunnel ever built

Tunnel construction

See how engineers dig tunnels and make them safe

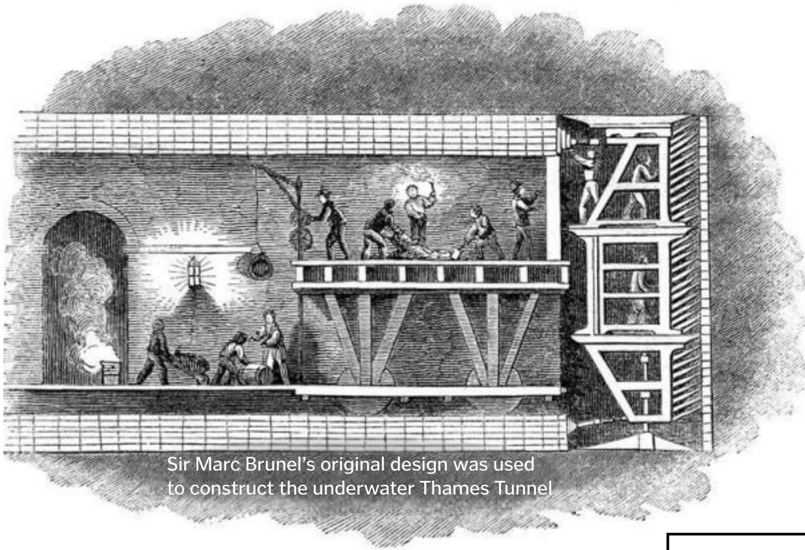


Excavating a tunnel is a complicated and potentially dangerous procedure, depending on the methods used and the type of ground being dug through. Tunnel-boring machines (TBMs) help to make the entire process safer and more efficient, and they are able to tackle tough terrain such as rock, which would be all but impossible to dig through by hand.

These enormous contraptions are fitted with cutting wheels, which are pressed against the rock and rip it apart as they spin. When the head turns, it slices through the rock and reduces it to rubble. This waste is dumped onto a conveyor belt, which transports it to the machine's rear where it can be loaded onto a truck and removed. To make sure the machine doesn't stray off course, two drills protrude from the centre and cut into the tunnel's roof, holding the TBM steady while it works.

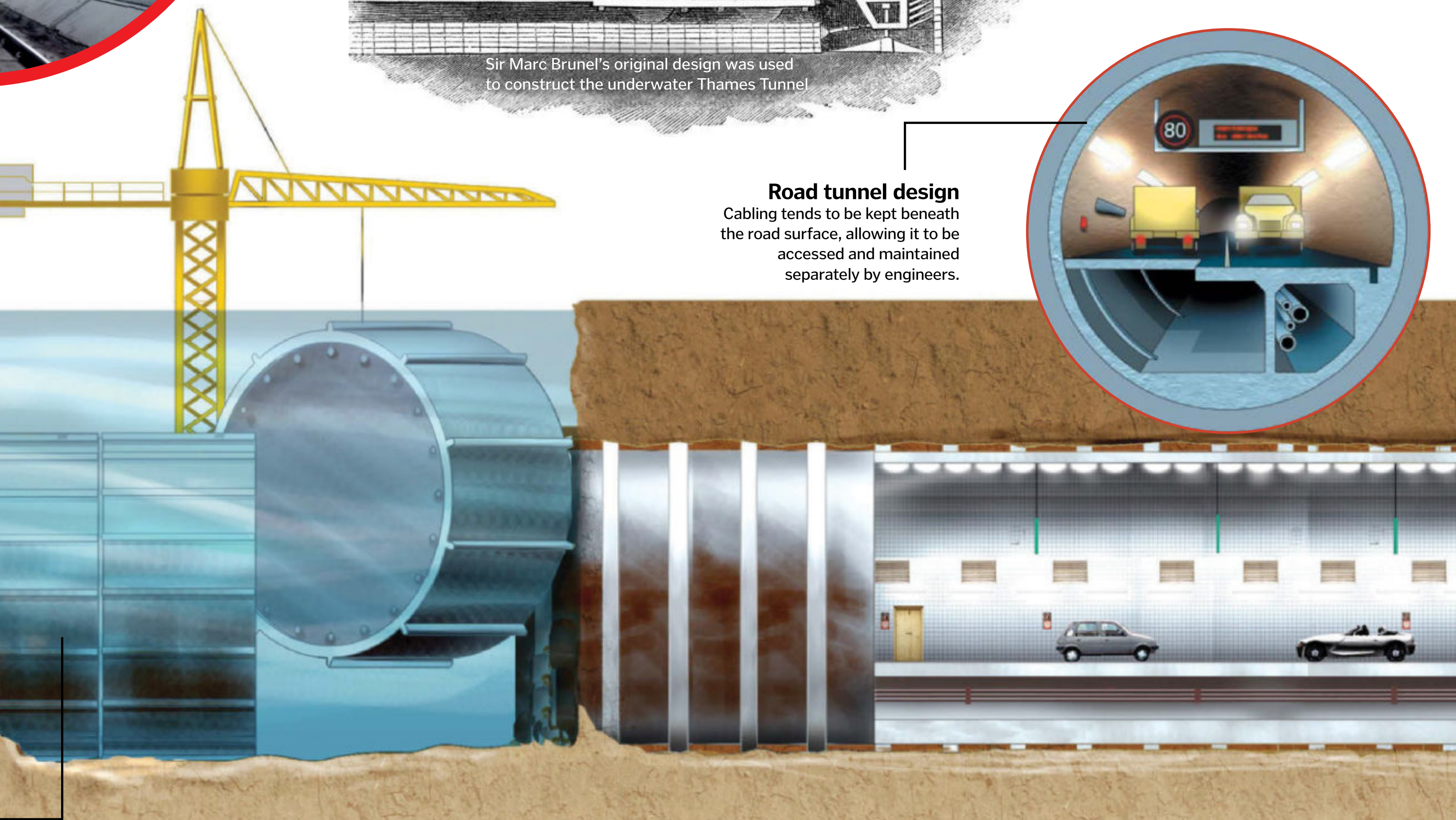
For digging through sand, silt and mud, there's a risk of the tunnel collapsing under the weight of the earth above, so TBMs rely on a tunnelling shield. Invented by Sir Marc Isambard Brunel in the 1800s, modern versions are large metal cylinders which hold the sides in place while the TBM continues to remove earth from the front. At the back of the shield is a set of hydraulic jacks, which propel the machine forward once a section is complete. While it advances, workers secure the tunnel's sides with fast setting concrete.

Even with this heavy-duty machinery, tunnels can take years to construct, but engineers are currently investigating new rock-cutting methods. From high-pressure water jets and electron beams to lasers and ultrasonics, these novel approaches could speed up the process in the future.



Sir Marc Brunel's original design was used to construct the underwater Thames Tunnel

"Cutting wheels are pressed against the rock and rip it apart as they spin"



Road tunnel design
Cabling tends to be kept beneath the road surface, allowing it to be accessed and maintained separately by engineers.

The world's longest tunnel

Beneath the Alps lies the record-breaking Gotthard Base Tunnel, which provides a shortcut through the towering mountains above. Spanning just under 60 kilometres, it has taken 2,000 workers 20 years to complete. The engineers used gigantic tunnel-boring machines to plough through an average of 30 metres of rock per day, excavating roughly 30 million tons of earth in total. The entire length of the tunnel is almost completely flat, enabling trains to travel faster and shaving an hour off the typical journey time between Zurich and Milan. An incredible feat of engineering, the tunnel cost Switzerland around £6.8 billion ($10.3 billion) to build, but it is expected to recoup much of this investment once passengers start using the service in June 2016.

The Herrenknecht Gripper tunnel-boring machine was used to cut through the mountain rock

Bone-conducting headphones

Who needs ears when you can listen to music through your skull?

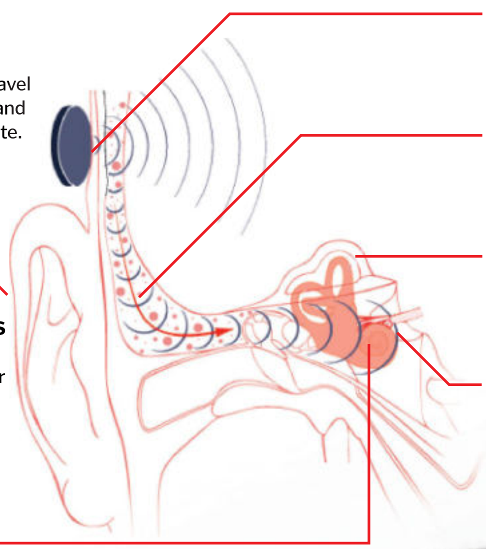
One major flaw with regular headphones is that you can't hear anything but the music being blasted into your ears. While this might be a blessing when sitting on a crowded train or bus, it also means that you won't hear a car come speeding towards you if you step into the road. Bone conduction offers a clever solution, sending the music straight to your inner ear so your outer ear remains free to pick up sounds from your surroundings.

The futuristic looking Batband is a device that uses this bone conducting technology. Its spring steel frame grips around the back of your head and can be paired with your smartphone or music player via Bluetooth. When you play music, three transducers – two on the sides of your head and one at the back – emit sound waves that vibrate through your skull to be picked up by your inner ear. Although 'bonephones' are nothing new, Batband is the first to be completely ear-free. It also features a microphone that can be used to make phone calls, and touch sensors on the sides allow you to adjust the volume or skip tracks with a simple tap or swipe.

Batband's touch sensors allow you to control it with simple hand gestures

How bonephones work

Normal hearing versus bone conduction



1 Normal hearing
Usually, sound waves travel through your outer ear and make the eardrum vibrate.

2 Good vibrations
The spiral-shaped cochlea in your inner ear converts the vibrations into electric impulses.

3 To the brain
The electrical impulses travel along the auditory nerve to the brain, which recognizes them as sound.

4 Bone conduction
When using bonephones, transducers on the side of the head emit sound waves that the temporal bone picks up as vibrations.

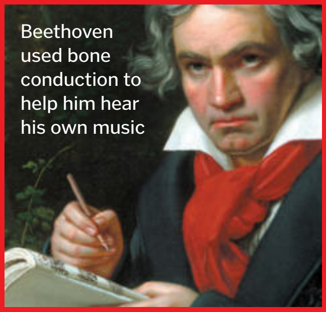
5 Straight to it
The vibrations travel through the skull to reach the cochlea in the inner ear, bypassing the eardrum.

6 Easy listening
The normal hearing process resumes as the cochlea transforms vibrations into impulses, which are sent to the brain.

How it was discovered

It may seem cutting-edge, but bone conduction was first discovered in the 16th century when sound was transmitted to the inner ear by way of a metal rod held between the teeth. At the time, it was believed that the sound was travelling through the Eustachian tube, which connects the middle ear to the throat and nasal cavity, but around 100 years later it was discovered that the skull was actually transmitting the vibrations.

As well as helping to diagnose hearing disorders, bone conduction tests also led to the development of the tuning fork in 1711 and even helped Ludwig van Beethoven. The famous 18th century composer was almost completely deaf, and so attached a metal rod to his piano and bit down on it as he played, sending the sound vibrations through his jawbone and straight to his inner ear. However, it wasn't until the 20th century that bone conduction was used to develop hearing aids.



Beethoven used bone conduction to help him hear his own music

What is 4D printing?

This technology can produce shape-shifting objects

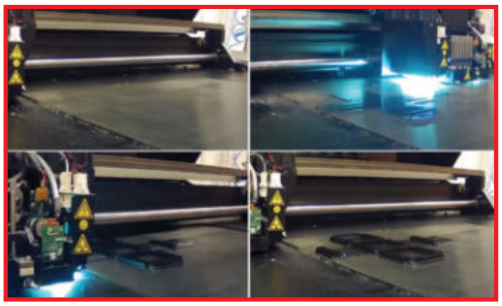
While 3D printing works by adding layer upon layer of a chosen material until a three-dimensional object is created, 4D printing produces objects that can transform over time. The process, which has been developed by scientists at Massachusetts Institute of Technology, involves feeding the printer a precise geometric code, defining exactly how the shape can bend and curl. This gives it the ability to change formation when it enters a different environment, such as water.

The system uses two different 3D-printed materials: one that remains rigid and another that can expand to fill 150 per cent of its original volume. The expanding substance is placed strategically to form joints that stretch and fold under certain conditions, allowing the entire structure to transform.

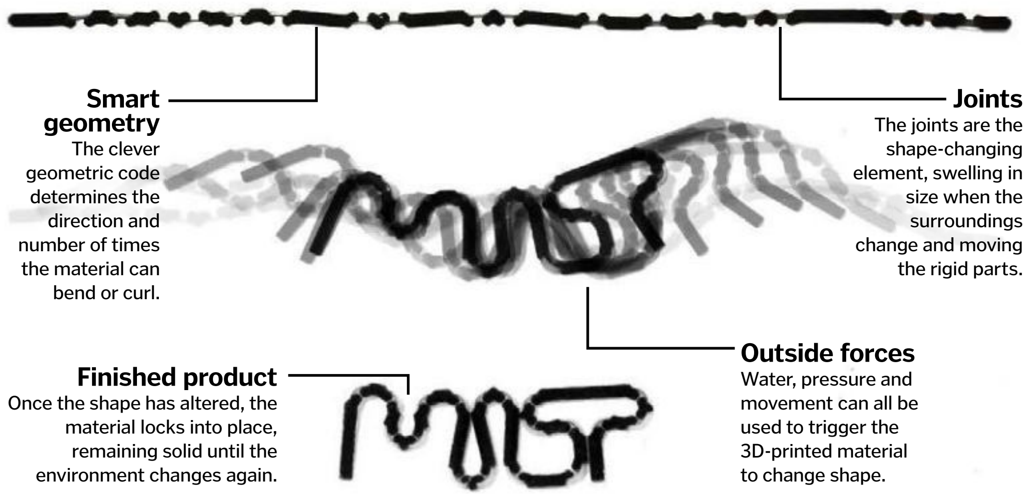
This technology could allow products to sense a change in pressure, temperature or moisture and adjust themselves accordingly. Pipes could expand or shrink depending on the presence of water, while trainers could adapt to different sports or terrain for optimal performance.

Self-adapting materials

See how 4D-printed objects can automatically alter their shape



The 4D process is similar to 3D printing, slowly building the object one layer at a time



Mapping the ocean floor

How we charted an area that covers over 70 per cent of Earth's surface

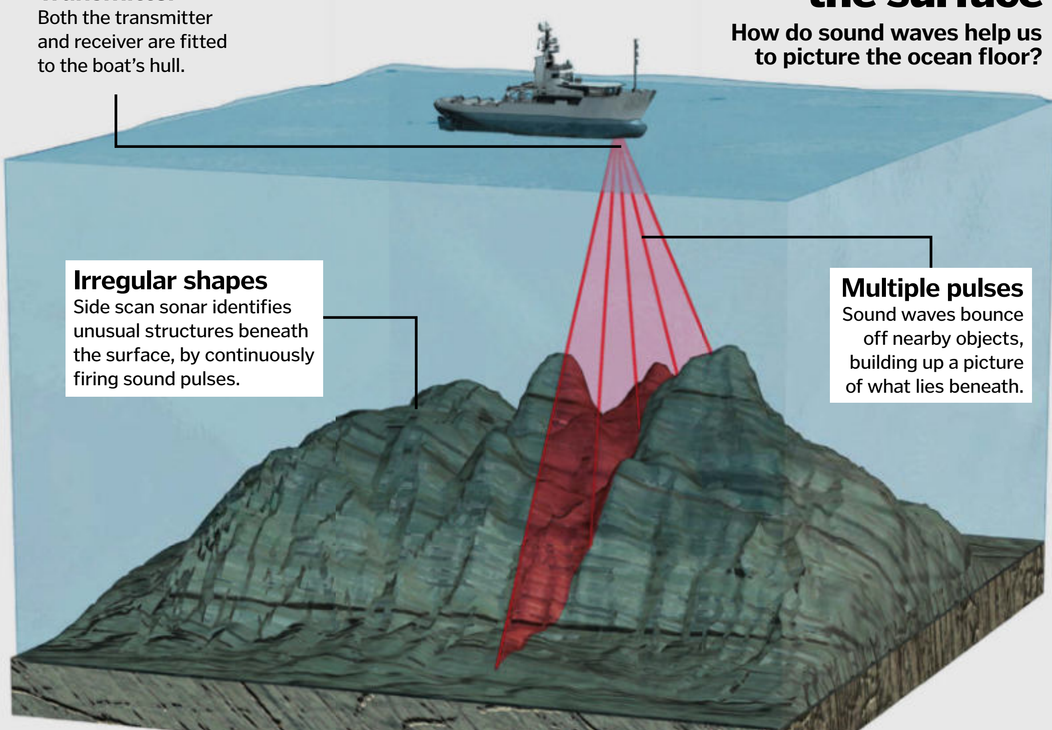
Multibeam sonar (sound navigation and ranging) uses sound waves to calculate the depth of water. A transmitter on the bottom of the vessel fires numerous pulses of sound, called 'pings', towards the seafloor, and once the sound waves hit something solid they're reflected back up to the receiver. The faster the pulses travel back to the boat, the smaller the distance they've travelled and therefore the shallower the depth of the water below.

Working in conjunction with this is a system called side scan sonar. Rather than firing pulses straight down, this transmitter emits sound waves in all directions below the surface. The reflected sound waves help to build a more comprehensive picture of the ocean floor, covering a distance of 100 metres.

Specialist computer software compiles the readings from both systems, and produces an overall map of the area. This is incredibly useful for scientists studying plate tectonics, modelling ocean currents or mapping the habitats of marine wildlife.

Seeing beneath the surface

How do sound waves help us to picture the ocean floor?



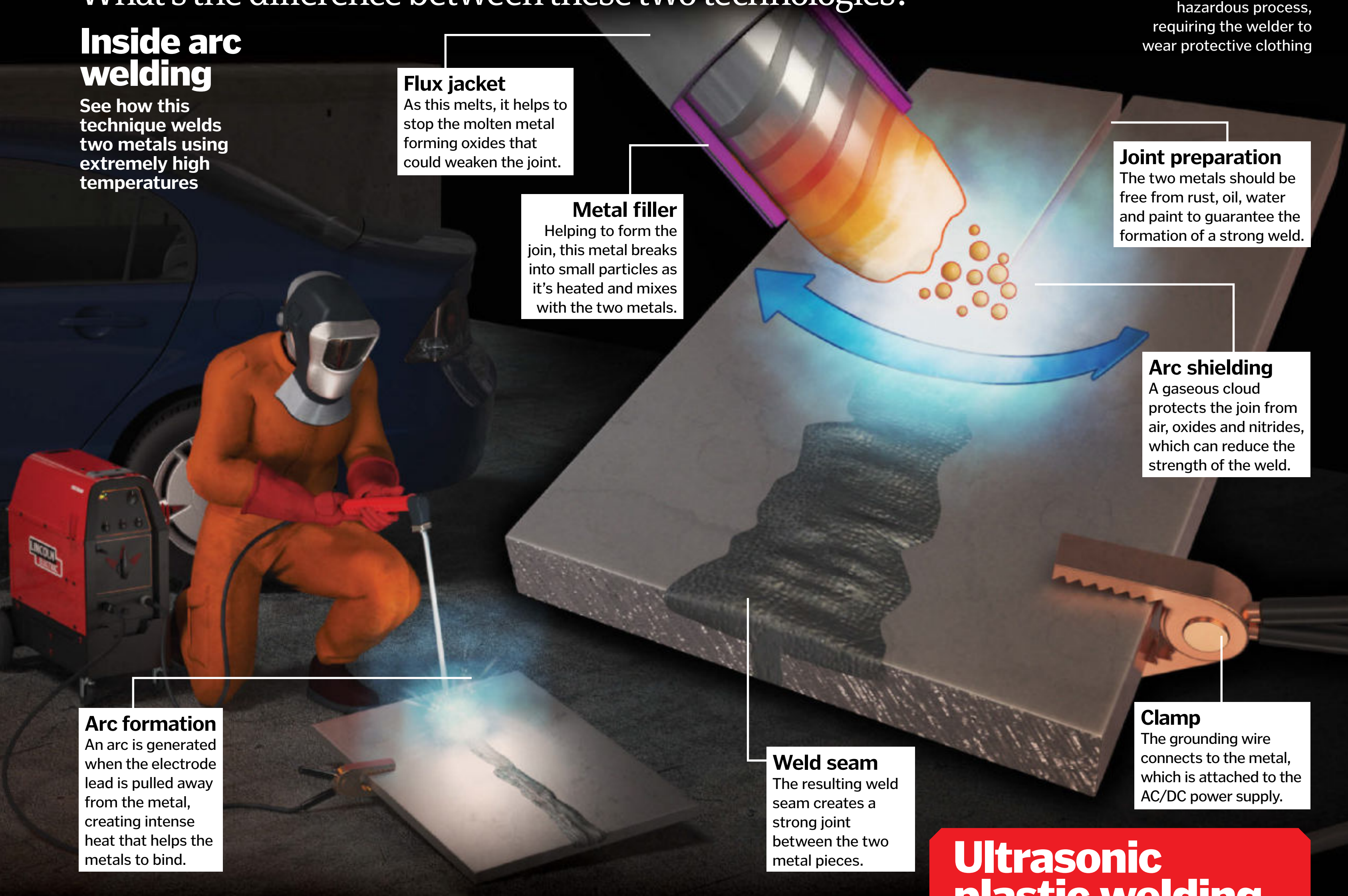
Arc welding versus ultrasonic welding

What's the difference between these two technologies?

Arc welding is a hazardous process, requiring the welder to wear protective clothing

Inside arc welding

See how this technique welds two metals using extremely high temperatures



Welding has advanced dramatically since the days of pounding two pieces of heated metal together. There are now many different methods used in electronics and medical devices, as well as in the metal structures this process was originally designed for.

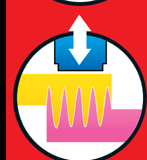
Arc welding uses an electric arc to melt two metals together. First, a grounding wire must be clamped to the welding material, which is connected to an AC/DC power supply. Another wire, called the electrode lead, is then placed on the metal's surface, and when this is lifted off, an electrical arc is created. It looks like small sparks, but is actually a continuous discharge of plasma produced when gas is broken down by electricity.

When the arc is generated, it produces extremely high temperatures that melt the two pieces of metal, as well as the metal filler at the electrode's tip, which acts as a binding agent to help fuse the materials.

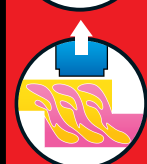
Ultrasonic welding uses a different technique. High frequency sound is used to produce rapid vibrations, which cause the materials to rub together and become hot. In most metals, this heat is roughly one third of the melting temperature, and removes the metal's outer layers. Exposed metal atoms move between the surfaces and form bonds. In plastics, ultrasonic welding actually melts the two materials, helping the plastic molecules to mix and form bonds.

Ultrasonic plastic welding

Applying pressure
A tool called a sonotrode presses down on the two plastics that are to be welded in order to amplify the vibrations' effect.



Vibrations
The sonotrode vibrates at around 40,000 times a second, generating heat. The plastics melt, mix and form bonds.



The weld
Once the plastic has cooled down, the sonotrode is carefully retracted and the weld is complete. This process is clean, fast and safe.

Extreme oceans

Counting down the deepest, deadliest, stormiest and downright most hostile environments on Earth

Where: New South Wales, Australia
Oceans: Tasman Sea / South Pacific

1 Most shark-infested

Just like Jaws, only less cinematic trickery and more lose-a-leg scary

When it comes to shark attacks, there are three species that sit firmly at the top of the food chain: the great white shark, the tiger shark and the bull shark. This is one gnarly trio of hungry fish, who are all keen predators with heightened senses.

The most extreme place on Earth for shark attacks recently is New South Wales coast in Australia and over the last year the country has seen two fatalities, 29 attacks and 18 injuries. It's thought that changing ocean currents are bringing the sharks' prey closer to shore, luring in the ocean beasts alongside the fish.

However, before you march out with your torch and pitchfork to chase the sharks from the bays, it's worth bearing in mind that many more people are killed by the water that sharks swim in than by shark attacks themselves. Humans are naturally not a good diet choice for a shark – we are too bony with far too little blubber on us. Sharks need prey that is high in fat, such as seals.

Very often a great white shark will bite a human as a curious nip to find out what they are, rather than in an attempt to feast on them. That said, when you're swimming in an area with a known shark presence, the best advice is to get out of the water. Swim calmly and smoothly, as thrashing around will only draw the shark's attention, and don't ever wear jewellery or anything shiny that could make the shark think that you're a tasty fish covered in scales.

65,000 km
Length of the Mid-Ocean Ridge

31 DAYS
The longest-lasting hurricane

WHERE ARE THEY?

The subterranean canyon off the coast of Nazaré creates incredibly tall waves, making it a popular surfing spot

2 Tallest waves

It's the stuff of every big-wave surfer's dreams: the 30-metre wave. Praia do Norte near the coastal village of Nazaré in Portugal is at one of the most westerly points of Europe, and bears the brunt of the sweeping Atlantic swells. Europe's largest underwater canyon, Nazaré Canyon, lies just offshore, which is a 200-kilometre long ravine that works to combine the energy from waves that have travelled across the Atlantic, currents from the canyon, gusting winds and local tidal forces into colossal waves.

Where: Nazaré, Portugal
Ocean: Atlantic Ocean

3 Fastest growing

Plate tectonics can cause chaos through earthquakes, but they can also cause oceans to grow. The region offshore from Chile and Peru on the East Pacific Rise, where the Pacific plate is pulling away from the Nazca plate, is the site of the fastest seafloor spreading on Earth. This is where two plates pull away from each other, and magma bubbles up from the Earth's core to fill the gap. In this region, up to 16 centimetres of new seafloor is produced per year.

Where: East Pacific Rise
Ocean: Pacific Ocean

4 Extreme storms

Where: Tropical Pacific
Ocean: Pacific Ocean

Is there such a thing as the 'perfect storm'?

Fishermen who make their living out on the waves, battling everything the Pacific throws at them, will tell you that this is one of the cruellest oceans on Earth.

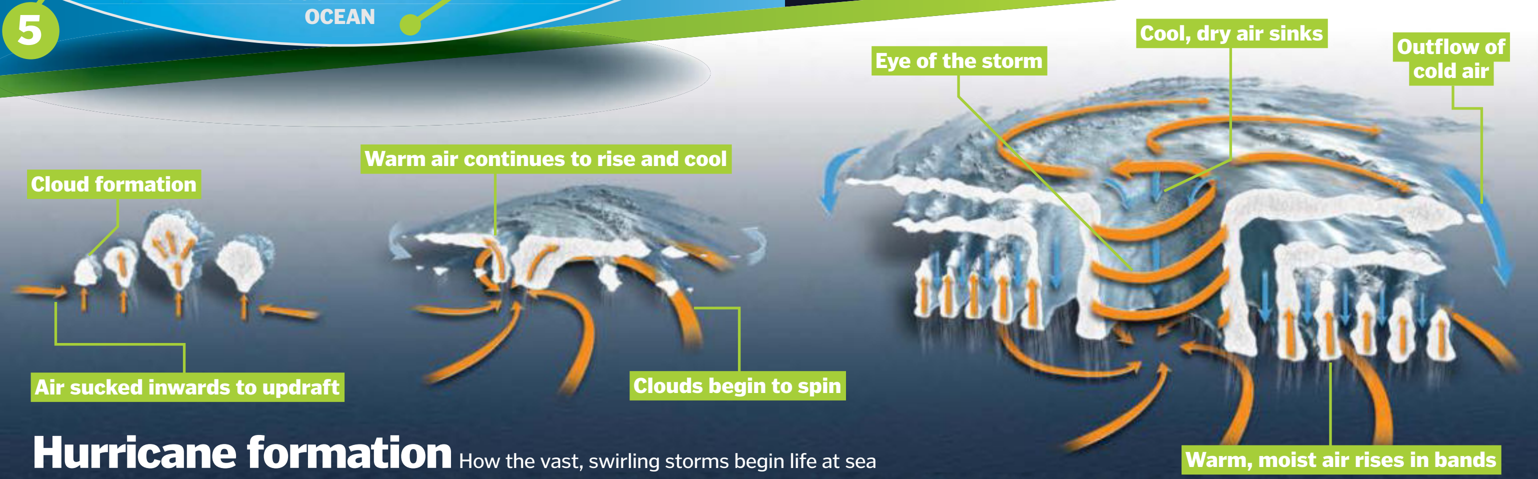
It's the tropical region that whips up this meteorological frenzy and creates the mother of all storms: hurricanes. Fed by very warm, moist air, these weather systems usually form between June and November, and need to reach 120 kilometres per hour or more to be classified as a hurricane, typhoon or cyclone. These three terms describe the same event and just depend on the origin of the storm. In the Atlantic and Northeast Pacific the storms are hurricanes; in the Northwest Pacific they're known as a typhoon; and in the South Pacific and Indian Ocean the weather system is termed a cyclone.

Hurricanes can travel huge distances across oceans, spinning anticlockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere, fed by the warm conditions of the tropics.

A storm name is retired if, like Katrina, it has had catastrophic effects

1.3bn km³
Amount of water (approximate) in the oceans

WHERE ARE THEY?



Hurricane formation

How the vast, swirling storms begin life at sea

1 Cloud formation

Over warm, tropical waters, seawater begins to evaporate. As it rises, it cools to rapidly form clouds. Cooler air from the surrounding area rushes in to replace the warm air, which then warms up and rises again, causing updrafts.

2 Rotation begins

The warm air continues to rise, cool and suck in more air from the surroundings below, gaining energy. As the Earth rotates, the clouds start to spin too. A hurricane is formed once wind speeds reach 120km/h.

3 Mature storm

Warm, moist air continues to rise from the ocean and forms clouds in bands around the eye of the storm. Cool, dry air sinks through the eye and also flows out between the cloud bands at the edges of the storm.

5 Deadliest

An entire ocean poised and ready for destruction

Beneath the Pacific Ocean lies a patchwork of molten terror known as the Ring Of Fire. Earth's crust is made up of tectonic plates that fit together like a jigsaw, floating over a layer of molten rock. At boundary zones, plates rub against each other, push against one another or pull away from one another, each with differing consequences. In the Pacific Ring Of Fire, the landmasses that surround the ocean are at the boundaries of these plates. Home to 90 per cent of earthquakes, the Ring Of Fire is a hotbed of tectonic activity.

Where: South America, North America, across the Bering Strait, Japan and New Zealand
Ocean: Pacific Ocean

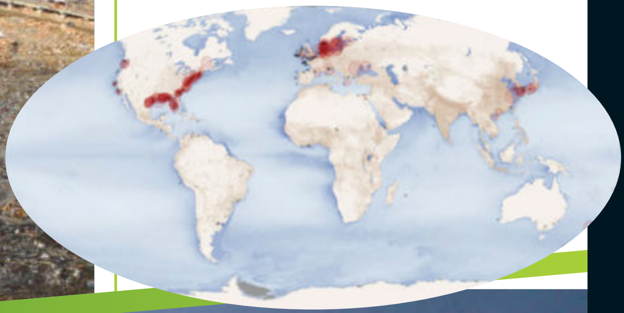
In 2011, an earthquake caused devastation in Japan, which is on the edge of the Ring of Fire

Where: Gulf of Mexico dead zone
Ocean: Atlantic Ocean

6 Most polluted

The dead zone in the Gulf of Mexico is one of the most extreme cases of ocean pollution. It covers almost 17,000 square kilometres of hypoxic water – where very little or no oxygen is present. Nothing can grow there, as almost all organisms require oxygen to survive. Dead zones are caused by nutrient runoff from the land (such as agricultural fertilisers) that cause an excess of algal growth. When the algae dies, it decomposes and consumes all of the oxygen in the water.

Dead zones occur in various oceans and inland water bodies, shown here with red dots



Where: Bay Of Fundy, Canada
Ocean: Atlantic Ocean

7 Most extreme tides

At the head of the Bay of Fundy, at the right time of the month, the difference in high tide and low tide can be a huge 16 metres. When the tide is this high, the bay fills and empties 100 billion tons of seawater during each tidal cycle. The huge tide is a result of the bay's shape and depth, as the water within the bay oscillates (like water sloshing from one end of a bathtub to another) in sync with tides from the Atlantic.

The Bay of Fundy stretches for 270km along Canada's east coast and is a tourist hotspot

Where: Surrounding Antarctica
Ocean: Southern Ocean

8 Coldest

Welcome to life in the liquid freezer

At the very bottom of the globe, surrounding frozen Antarctica, swirls the untameable Southern Ocean. It's home to some of the fastest winds and tallest waves, and also boasts the largest ocean current (the Antarctic Circumpolar Current) that transports more water than all the world's rivers combined. Temperatures can reach a bitterly cold -2 degrees Celsius, because the ocean's salinity lowers its freezing point.

Animals that live in the Southern Ocean also have to adapt to survive. Extra layers of blubber and super-insulating feathers are just a few adaptations, but one of the most extreme has to be that of the Antarctic icefish. This critter has evolved a type of 'antifreeze' protein to prevent ice crystals forming in its body when the temperature plummets.

1,000 YEARS
Time for $1m^3$ of water to travel around the world's currents

An incredible feat of survival, the icefish can survive temperatures of -2˚C

10,000–50,000
Number of icebergs produced in the Arctic annually

The Southern Ocean is home to the coldest and stormiest waters on Earth

9 Deepest

Where: Mariana Trench
Ocean: Pacific Ocean

Take a breath and dive deeper than Everest is tall

Surviving in the abyss

What lives in the deepest parts of the ocean?

EPIPELAGIC ZONE
The uppermost layer of oceanic water receives enough light to allow photosynthesis to occur.

MESOPELAGIC ZONE
Sometimes known as the 'twilight' zone, this extends from 200-1,000m down, where the light disappears completely.

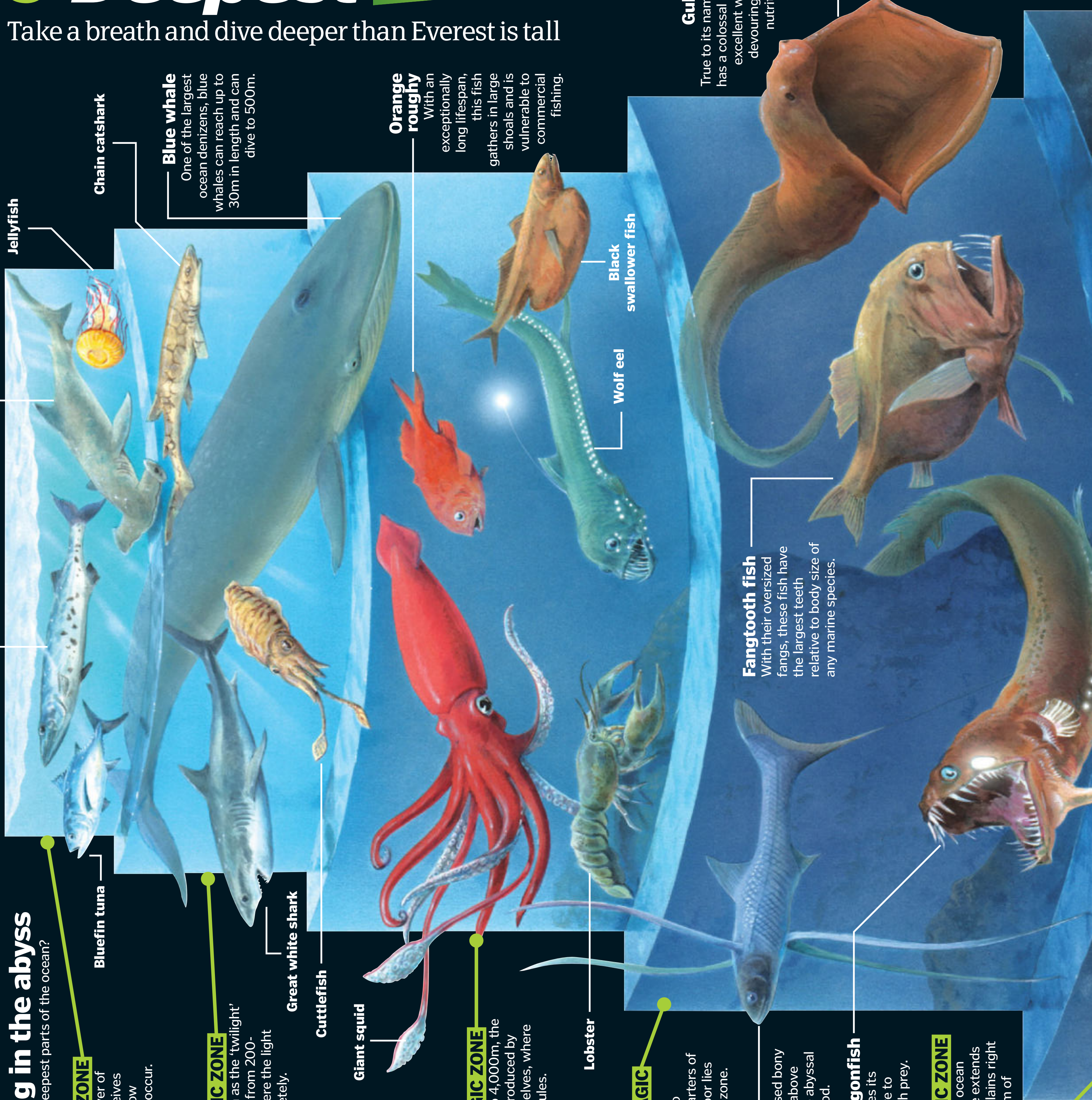
BATHYPELAGIC ZONE
Extending down to 4,000m, the only light here is produced by the animals themselves, where bioluminescence rules.

ABYSSOPELAGIC ZONE
Stretching down to 6,000m, three quarters of the deep-ocean floor lies within the abyssal zone.

Tripod fish
This fish's specialised bony fins help it to rest above the thick silt of the abyssal plain in wait for food.

Deep-sea dragonfish
The dragonfish uses its bioluminescent lure to attract and ambush prey.

HADOPELAGIC ZONE
Encompassing the ocean trenches, this zone extends from the abyssal plains right down to the bottom of the world.



Blue whale
One of the largest ocean denizens, blue whales can reach up to 30m in length and can dive to 500m.

Orange roughy
With an exceptionally long lifespan, this fish gathers in large shoals and is vulnerable to commercial fishing.

Fangtooth fish
With their oversized fangs, these fish have the largest teeth relative to body size of any marine species.

Gulper eel
True to its name, this eel has a colossal mouth, an excellent weapon for devouring large and nutritious prey.

At the very bottom of the ocean, just shy of 11,000 metres below the surface, sunlight is long gone and all that is left is inky blackness. The Challenger Deep is part of the Mariana Trench, a deep score across the sea floor of the Pacific basin that is formed at a subduction zone, where one tectonic plate disappears beneath another. It is the deepest point in Earth's oceans, and with over ten kilometres of water overhead, the hydrostatic pressure is 1,100 atmospheres – the equivalent of inverting the Eiffel tower and balancing it on your big toe.

The water temperature at the bottom of the Challenger Deep is just above freezing, and the trench is filled with clouds of silt, formed from millions of years of ocean garbage falling from above and slowly rotting away. However, despite the pressure, darkness and coldness of the environment, life still prevails! The deep sea is home to an array of strange and wonderful creatures that survive against all odds, having developed clever mechanisms to deal with the extreme conditions.

The Challenger Deep was first explored in 1960 by Swiss scientist Jacques Piccard and US Navy Lieutenant Don Walsh in the Trieste submersible, which set a record by diving to a depth of just over 10,915 metres. Since that seminal dive there have been multiple attempts by both manned and unmanned vehicles, the most recent made by explorer and film-maker James Cameron, who managed to reach a depth of 10,898 metres in his Deepsea Challenger submarine.

Hydrothermal vents

Often forming at mid-ocean ridges where tectonic activity is high, hydrothermal vents are cracks and fissures in the Earth's crust where super-heated water escapes into the ocean. The temperature of this water can reach 400 degrees Celsius, but doesn't boil due to the extreme pressure.

Hydrothermal vents can support vast communities of life. The organisms that live around them use chemosynthesis – as opposed to photosynthesis – to survive. The primary producers of a chemosynthetic food chain are microbes that use the chemicals expelled by the vents as the basis to create energy, akin to how plants on land use sunlight.


Seawater filters through the rocks into the crust, becomes super-heated and is expelled through vents

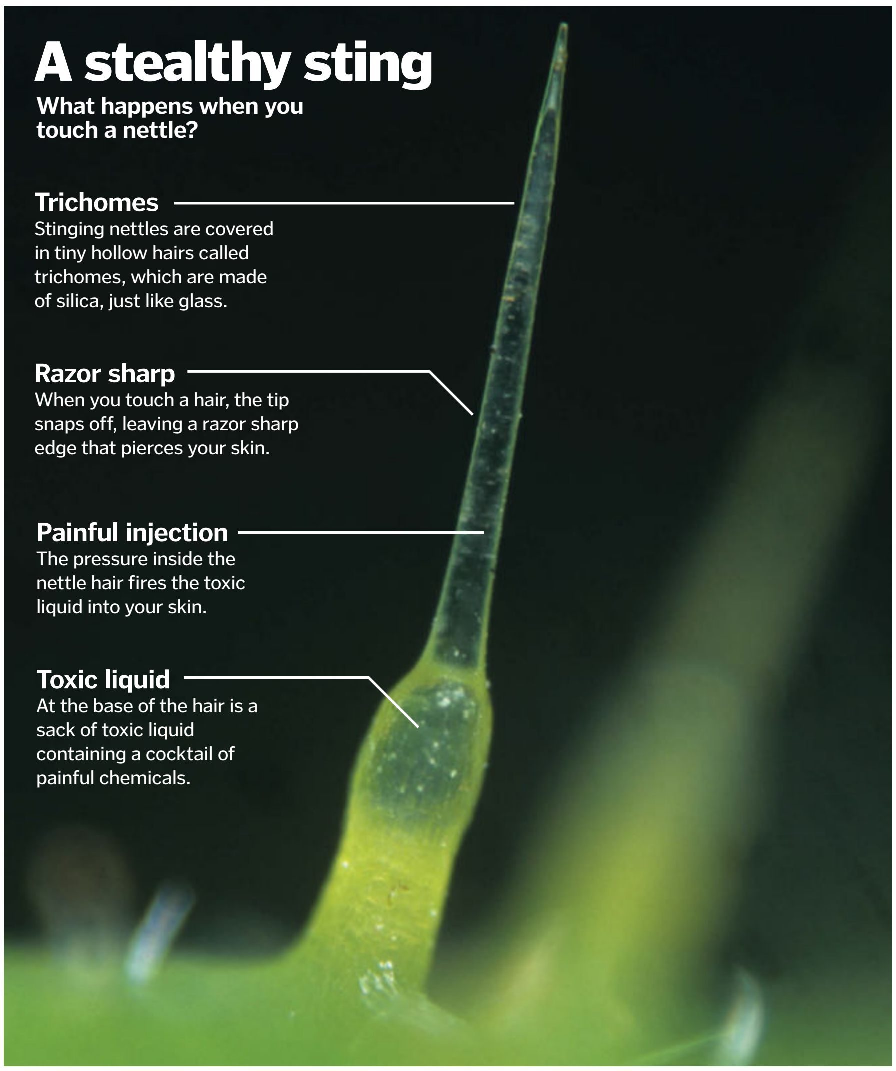
How stinging nettles get under your skin

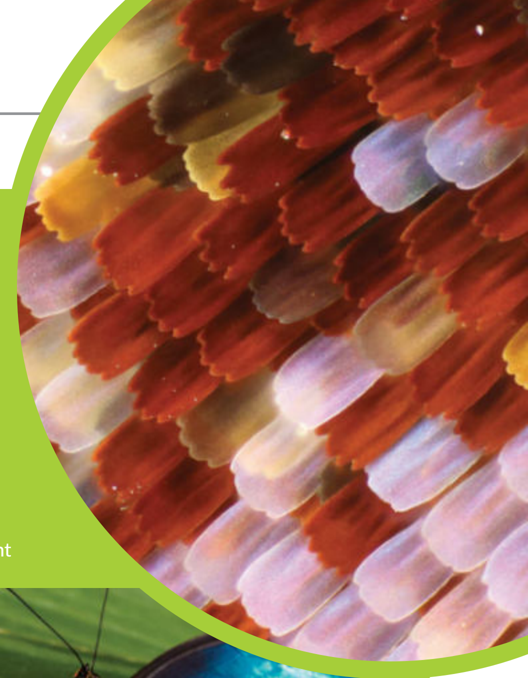
The injection of toxic chemicals that leaves you in agony

Stinging nettles can ruin a walk in the countryside, causing a searing pain if you brush your leg against them. The stinging sensation can last for hours, but it's still not clear what causes it.

What we do know is that nettles are covered with lots of tiny hairs that act like needles. When you come into contact with these hairs, they pierce your skin and inject you with a cocktail of chemicals, only some of which have been identified. One known component is formic acid, which is also found in ant venom. Although this is capable of producing a sting, it is only present in very low concentrations, so is unlikely to cause the pain.

Two neurotransmitters in the liquid, serotonin and acetylcholine, are thought to have more impact, sending signals to your brain that are interpreted as pain, while histamine causes inflammation of the skin. Nettles use this self-defence mechanism to stop animals eating them.





The individual scales of a butterfly wing can be seen in this coloured scanning electron micrograph

The blue morpho butterfly's transparent wing scales reflect blue wavelengths of light

Butterfly wings under the microscope

Discover the tiny structures that make them shimmer

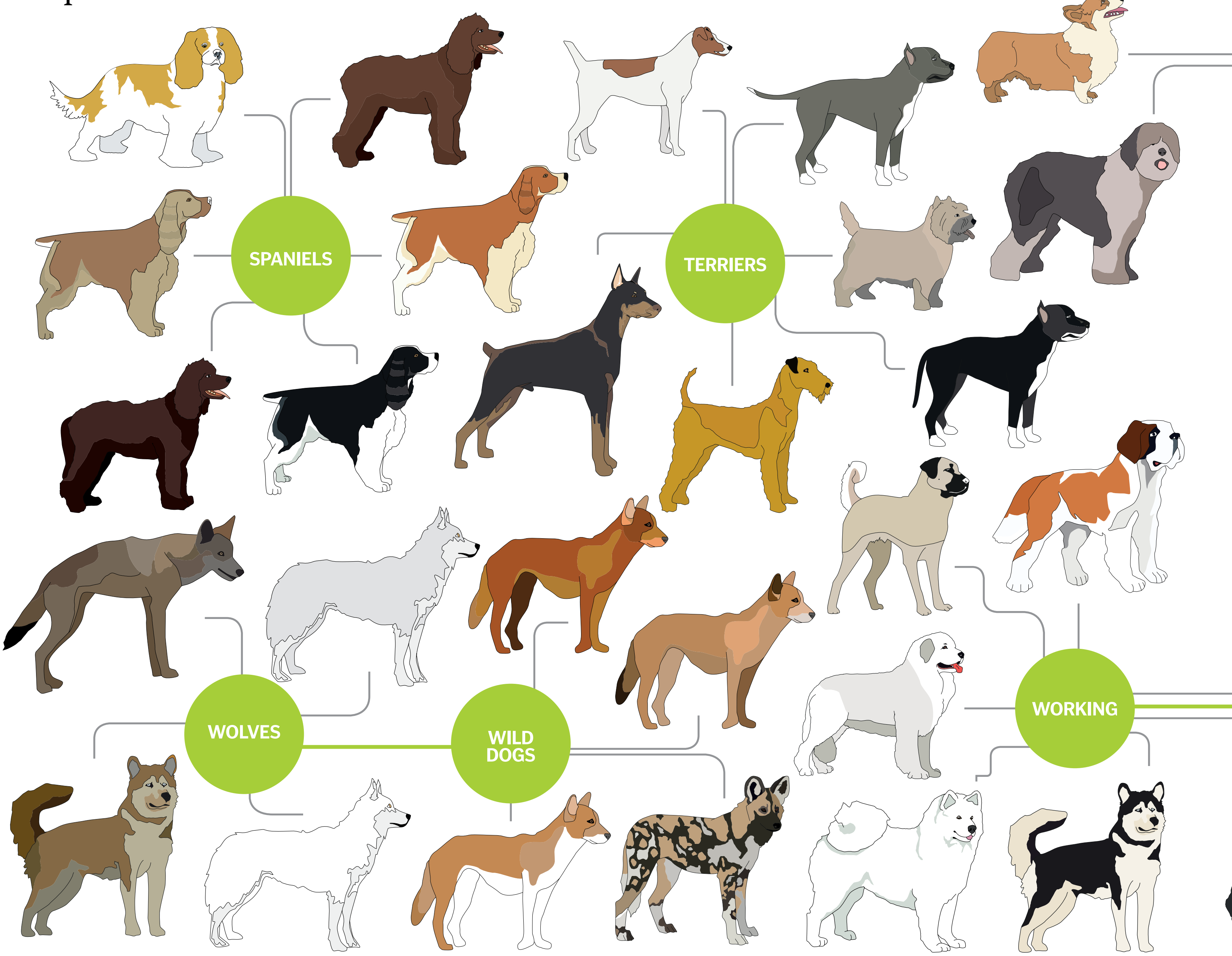
In the rainforests of South America, the blue morpho butterfly can often be seen glimmering in the sunlight with its wings changing from brilliant turquoise to electric blue as they flutter. This clever trick is used by many species of butterfly and moth, and is a result of the insect's incredible wing structure.

A butterfly's wings are covered in several layers of tiny scales, which give them their colourful patterns in two different ways. Some scales contain a chemical pigment that reflects just one wavelength of light, creating one unchanging colour. However, some butterflies also have transparent scales that cause iridescence. As light hits the top layer of these scales, some wavelengths are reflected straight away while others pass through and are reflected by the next layers. If the two wavelengths line up when they are reflected back towards your eyes, the colours become much more intense.

When the butterfly moves its wings, light hits the scales from many different angles, causing varying wavelengths to be reflected for a dazzling, colour-changing display.

The diversity of dogs

From the Chihuaha to the bulldog, man's best friend is just one species: Canis familiaris



Wolves and wild dogs

Our four-legged friends evolved from wolves as a result of domestication and selective breeding. Although domestic dogs still show traits of their ancestry, such as marking territory and burying belongings, they are now a different species to their wild relatives.

Terriers

These dogs are often (but not always) small, wire-haired and feisty, and were originally bred as vermin-catchers in the 19th century. The word terrier comes from the Latin word 'terre', meaning 'earth', and refers to their tendency to dive into burrows, barking furiously to flush out rodents, foxes, badgers and more.

Northern

Northern dog breeds hail from bitterly cold countries. The likes of Siberian huskies, Alaskan malamutes and Norwegian elkhounds are muscular breeds with thick fur. They were bred for hunting, herding and snow-sled pulling as well as for companionship and warmth!

Working

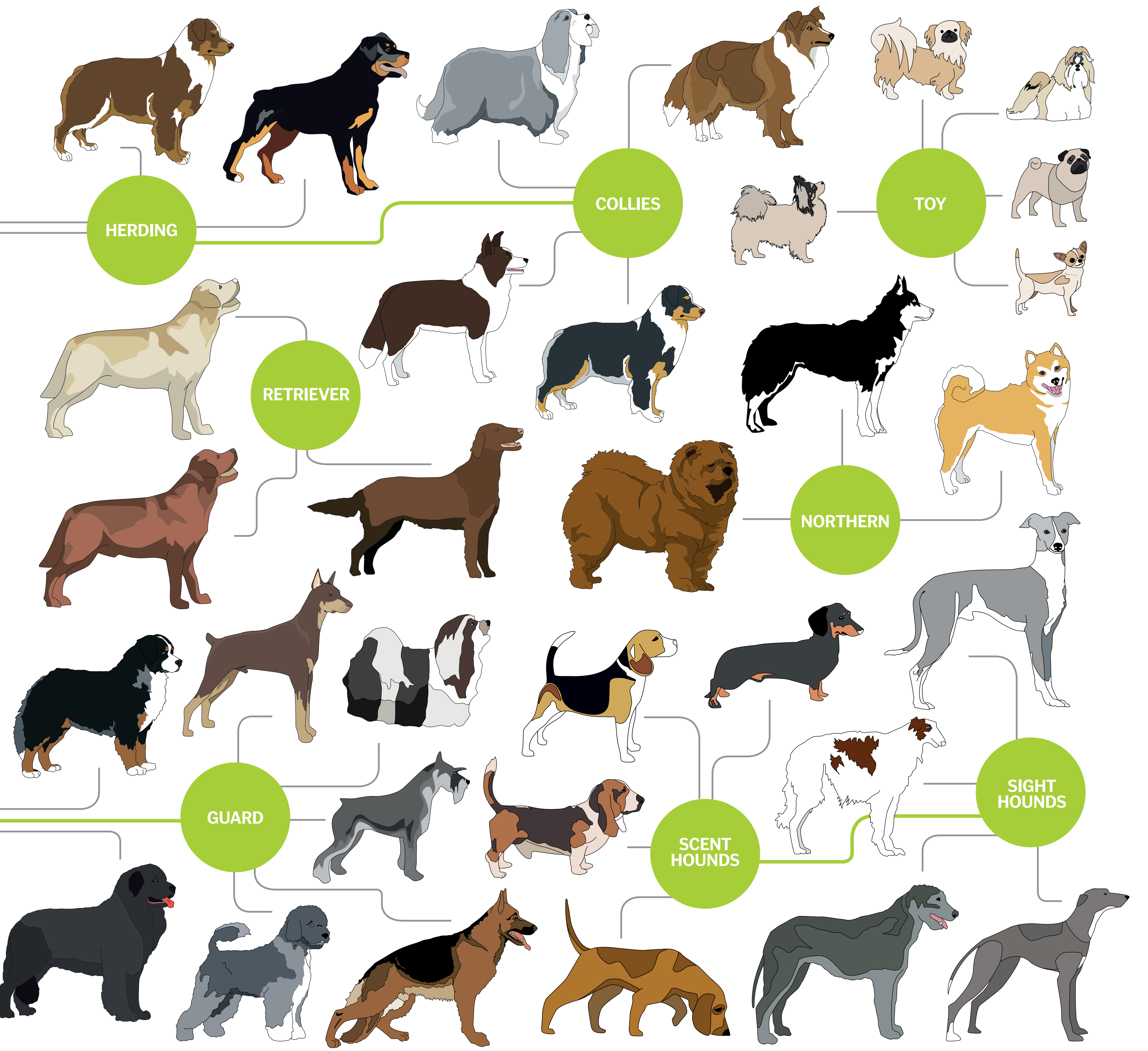
This group of canines is made up of strong and smart dogs that are bred for a purpose. Including Bernese mountain dogs, Great Danes, mastiffs, German shepherds and St Bernards, working dogs sniff out danger, perform searches and rescues, help with hunts and protect their families.

Spaniels

The quintessential spaniel look is that of a smooth, shiny coat and large, floppy ears. Including breeds such as springer spaniels and cocker spaniels, they are friendly and lively dogs originally bred as gun dogs, used to either flush out game for their masters to shoot, or to retrieve fallen kills.

Collies

Recognised as the brainiest bunch of dogs, collies are traditionally working and herding dogs. The border collie is perhaps the most famous for its intellect and agility, but other breeds such as bearded, rough-haired and smooth-haired collies are also able to complete relatively complex tasks.



Herding
Dogs have been used to herd other animals for a very long time, and this group contains a diverse array of breeds. For example, corgis were traditionally used to herd cattle, samoyeds are expert reindeer-herders and old English sheepdogs were used to move the woolly flock.

Guard
Breeds such as Dobermanns, Rottweilers and Staffordshire bull terriers are very loyal, and are big softies when they're with people they love and trust. When on duty however, their threatening appearance and deep bark make them excellent guard dogs, keeping even the bravest of intruders away.

Sight hounds
This group of dogs hunts with sight and speed. Including breeds such as whippets, greyhounds, Afghan hounds and Irish wolfhounds, sight hounds are slender and majestic, with long necks and straight muzzles. They're also the fastest dogs on Earth, have plenty of energy and love to chase.

Scent hounds
As their name suggests, scent hounds hunt with their noses. Breeds such as bloodhounds, beagles, foxhounds and dachshunds have large noses and wide nostrils, and have been used for centuries to track down people and animals. They are also used for detecting drugs and explosives because of their acute sense of smell.

Toy
These are the miniature dogs that can sit on your lap or nap in your handbag. Breeds such as the Chihuahua, bichon frise, German spitz klein and Pomeranian are all toy dogs, which are perfect for companionship. Some toy dogs have a feisty terrier-like side, but many just want to be cuddled.

Retriever
As part of the gundog group, retrievers were bred to bring back downed game from both land and water – many breeds love to swim! Including golden retrievers, Labrador retrievers, curly-coated and flat-coated retrievers, their loyalty and happy disposition make them excellent companions.

What causes drought?

How a slight shift in wind patterns can have terrible consequences

Drought occurs when an extended period of high pressure brings very little rain

For areas that rely on regular rainfall to nourish vegetation, animals and a large human population, drought can be devastating, but in other parts of the world, hot, dry weather is a normal everyday occurrence. These arid climate conditions are caused by circulatory patterns of air in the Earth's atmosphere, known as Hadley cells.

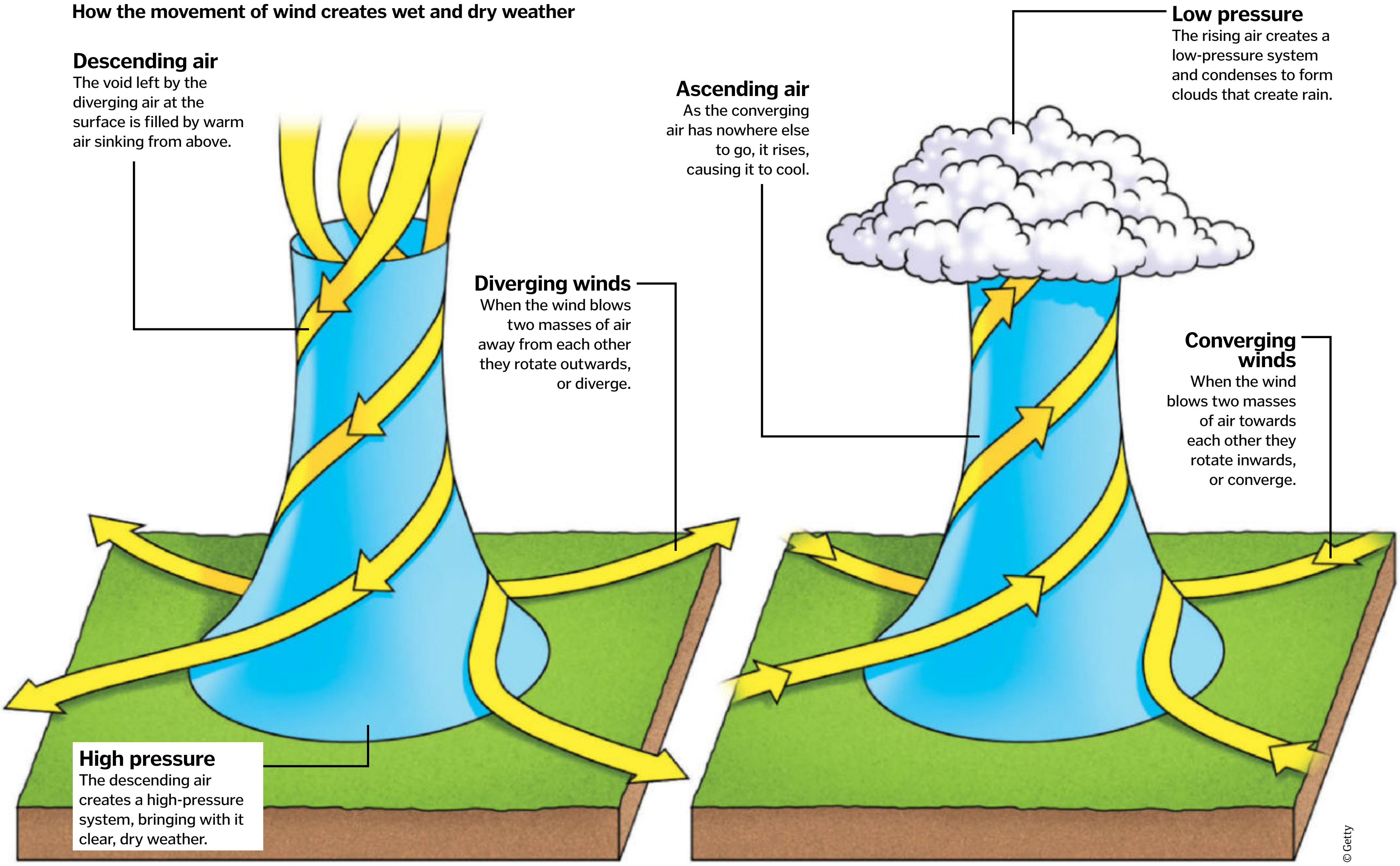
In this weather system, intense exposure to sunlight at the equator causes warm, moist air to rise. As the air rises, it cools again, forming a low-pressure system that results in regular thunderstorms across the region. Above these storms, the jet stream – a current that flows through Earth's upper atmosphere – carries the air towards higher latitudes until it eventually descends over the tropics north and south of the equator. As it falls, it creates a high-pressure system that is responsible for the arid conditions of the Sahara and other deserts that populate this region.

Slight changes in this movement of air can result in unusual – and sometimes catastrophic – weather activity, such as flooding and drought. For example, if the air that normally descends over the tropics in the Northern Hemisphere is carried further north by the jet stream, it can bring extended periods of high pressure to Europe. This can cause precipitation levels to fall below the expected average for the region, resulting in a period of non-seasonal drought.

Despite using advanced weather prediction models, experts are still only able to forecast drought when it is less than a month away, making it hard for countries to be prepared.

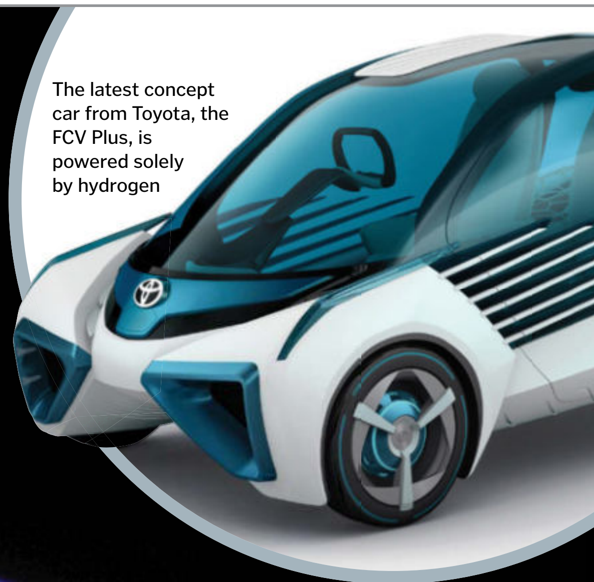
Convergence and divergence

How the movement of wind creates wet and dry weather



Fuel of the future

How will we power our vehicles when we exhaust Earth's oil supplies?



The latest concept car from Toyota, the FCV Plus, is powered solely by hydrogen

Reports indicate that roughly 1.2 billion vehicles occupy our roads, and this number is constantly on the rise. By the year 2035, this figure is expected to reach two billion. As traditional sources of fuel start to dwindle and prices keep on rising, it's imperative that we find alternative fuels.

Although there is no shortage of options, we are still searching for one breakthrough energy source that can bear the brunt of our requirements. Solar power, biofuels, wind and ethanol have all been suggested, but among the most viable replacements for petrol and diesel is hydrogen. It's the most abundant element in the universe and is environmentally friendly, as burning it produces water and heat, both of which can be recycled. The problem is that getting it into a form where it can be used as fuel requires energy to be spent, unlike oil or natural gas. Hydrogen is also difficult to store and currently, the infrastructure is not in place to distribute it to petrol stations. Hydrogen power is certainly promising, but while these issues remain, its use will be extremely limited.

Another popular alternative may be electric vehicles, which use rechargeable batteries instead of combustion engines to power motors. By 2020, many believe that electric cars will be priced similarly to traditionally fuelled vehicles. This has prompted scientists around the world to look at new methods for producing electricity. One option is to mimic photosynthesis – the process used by plants and other organisms to turn sunlight into energy – for commercial use. Recent breakthroughs mean that it's now possible to replicate the precise chemistry in the lab, which could pave the way for the creation of storable solar fuel.

The reality is that in the coming decades, the fuels we have relied on for so long will continue to be used, but the hope is that we can reduce our dependence on them. We've spent the best part of a century building a global economy around oil so it will take a long time for this to change. However, the scale of this issue means there is a global effort to develop eco-friendly alternatives that can replace fossil fuels.

Evaporation power

Learn how scientists have harnessed one of water's natural processes to drive a miniature vehicle

Evaporation is a fundamental part of the water cycle, where liquid turns into a gas due to an increase in temperature or pressure. Despite being a dominant form of energy transfer on Earth, this huge power source has remained untapped by scientists, until now. Researchers at Columbia University, New York, believe they have made a breakthrough, with the help of bacterial spores.

These spores typically exist in dry places, but when they are exposed to moisture they readily absorb it, and then shrink back when they return to a dry environment, where the water evaporates again. The spores stretch and contract like flexing muscles, depending on the presence of water in the air.

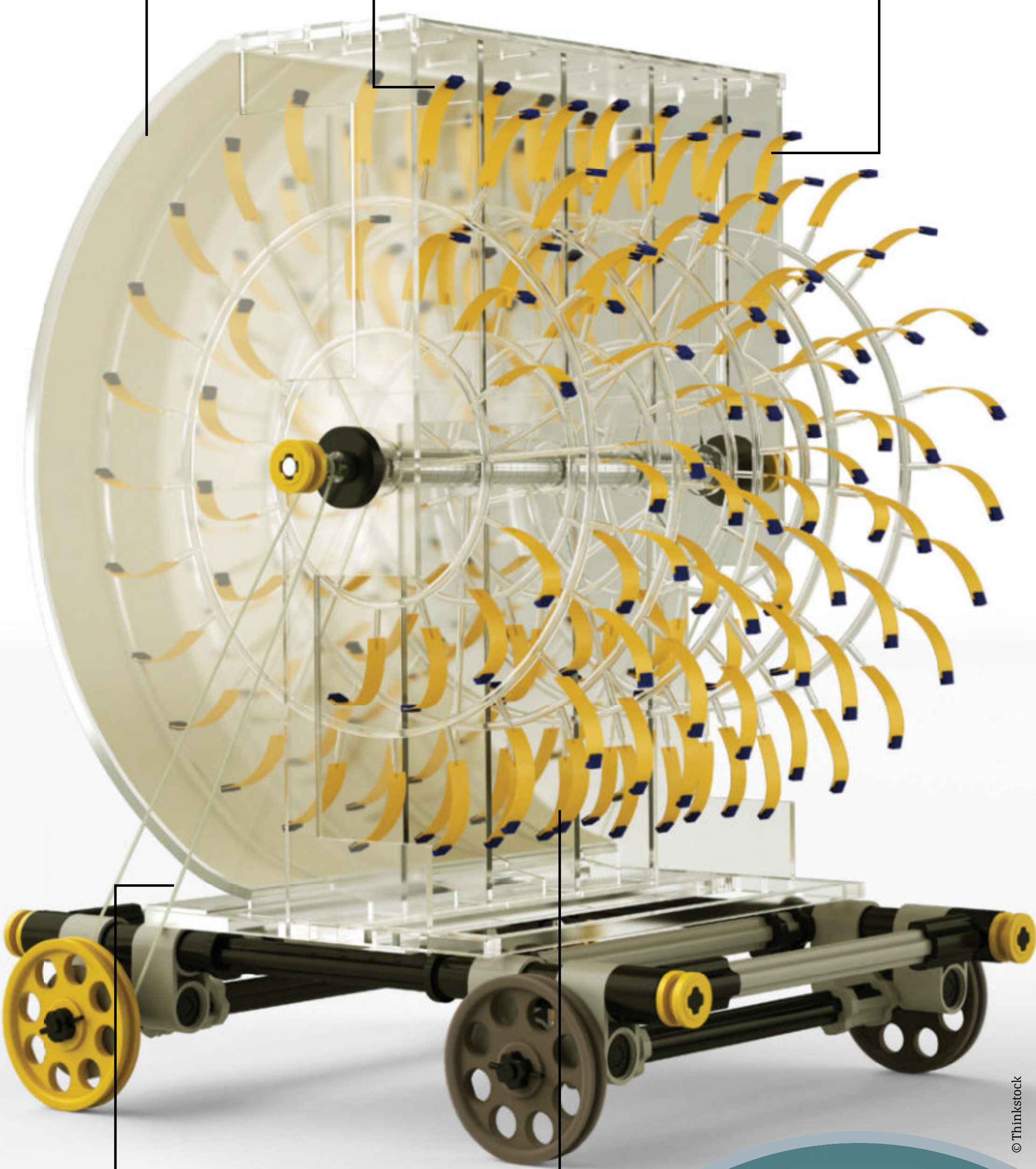
Scientists realised that this property could be exploited to power a system, and set about developing a device to showcase this. They added spores to small strips of plastic tape and increased the humidity so the spores expanded, lengthening the tape they were mounted on. When the researchers combined many lengths of tape together, they were able to increase the force that this bacterial action created.

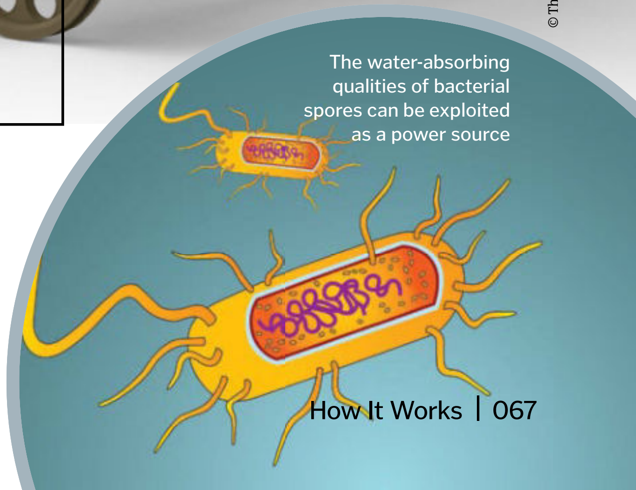
Using this principle, the experts have managed to create a working vehicle powered by a 'moisture mill', which is essentially a plastic wheel with a large quantity of tape-mounted spores around it. Half of the wheel is placed into a humid environment and the other half in a dry environment. As the spores expand when humidity is high and contract when it's low, a mass imbalance is created on the wheel, causing it to spin. To power a toy car, the scientists simply connected this spore engine to the wheels via an elastic band and, sure enough, the car moved steadily forward.

The number of potential applications for this technology is vast, but what excites scientists the most is that they can use evaporation to both produce energy and save water at the same time. It may be many years before we fill our vehicles' tanks with tap water, but this breakthrough proves that engines powered by evaporation might be more science than fiction.

The moisture mill

Take a look inside the ingenious evaporation engine





The water-absorbing qualities of bacterial spores can be exploited as a power source

‘Breathing’ batteries

New technology could help electric cars go the distance

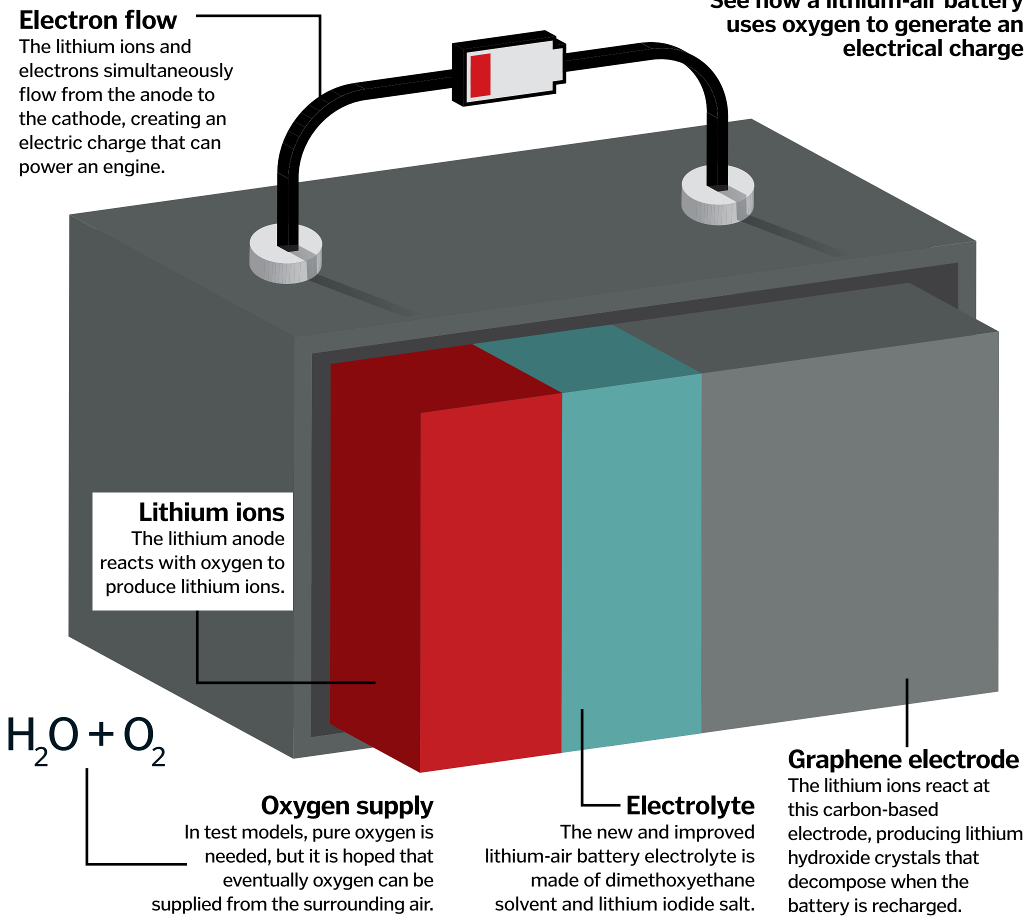
The efficiency of electric cars is unmatched by their fossil fuelled rivals, but they are held back by their limited range. Chemical engineers from the University of Cambridge believe they have overcome this obstacle by devising a lithium-oxygen battery that can be recharged more than 2,000 times. These ‘breathing’ batteries harness the energy produced when lithium reacts with oxygen in the air. Like all batteries, they have three basic parts, a positive electrode (the cathode), a negative electrode (the anode) and an electrolyte, which acts as a conducting medium to allow the flow of ions between the electrodes.

The key to the new design is a graphene cathode, which is a more resilient material than previously used forms of carbon. This works alongside a new electrolyte, which results in a by-product called lithium hydroxide. Instead of coating the anode as in previous designs (which gradually wears down the battery), this by-product decomposes with every charge.

With this technology, researchers hope that electric cars could be driven for as far as 800 kilometres on a single charge. Despite being a long way from featuring in a Nissan Leaf or a Tesla, these batteries bring us closer to long-distance electric cars than ever before.

Inside a breathing battery

See how a lithium-air battery uses oxygen to generate an electrical charge



Boeing’s eco technology

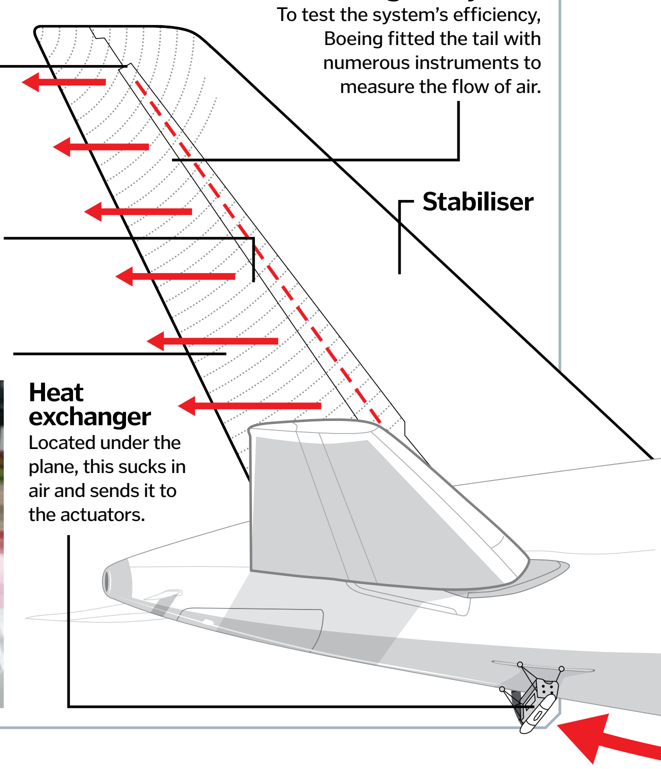
How a tiny tail tweak can make massive fuel savings

A passenger plane such as the Boeing 747 burns around four litres of fuel a second, which equates to 150,000 litres over a ten-hour flight. With roughly 100,000 commercial flights departing each day, airlines are keen to boost fuel efficiency by any means possible.

A good way of doing this is to make the plane lighter, which has prompted Boeing to experiment with the tail design on their planes. A smaller vertical tail, which has been trialled on their ecoDemonstrator 757, has 31 tiny devices that blow air directly onto it, known as sweeping jet actuators. These create the same side forces during take-off and landing as a larger tail, while reducing weight and therefore fuel consumption. The ecoDemonstrator 757 has made a series of successful test flights.

The ecoDemonstrator 757

With active flow control, Boeing’s smaller vertical tail provides excellent stability and directional control

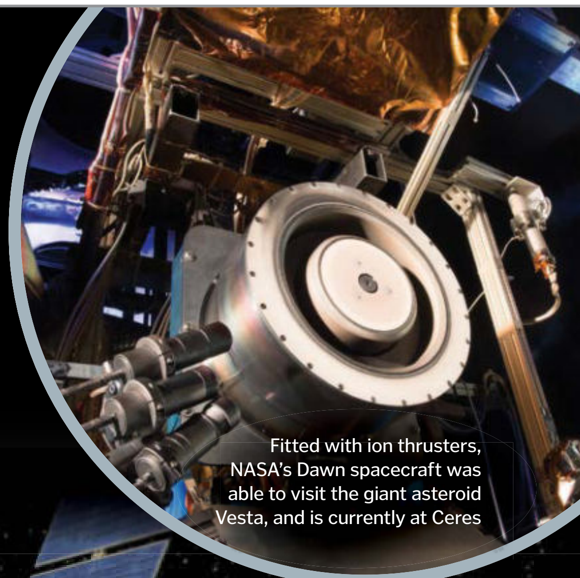


NASA has experimented with a non-stick wing coating to stop trapped insects from reducing fuel efficiency

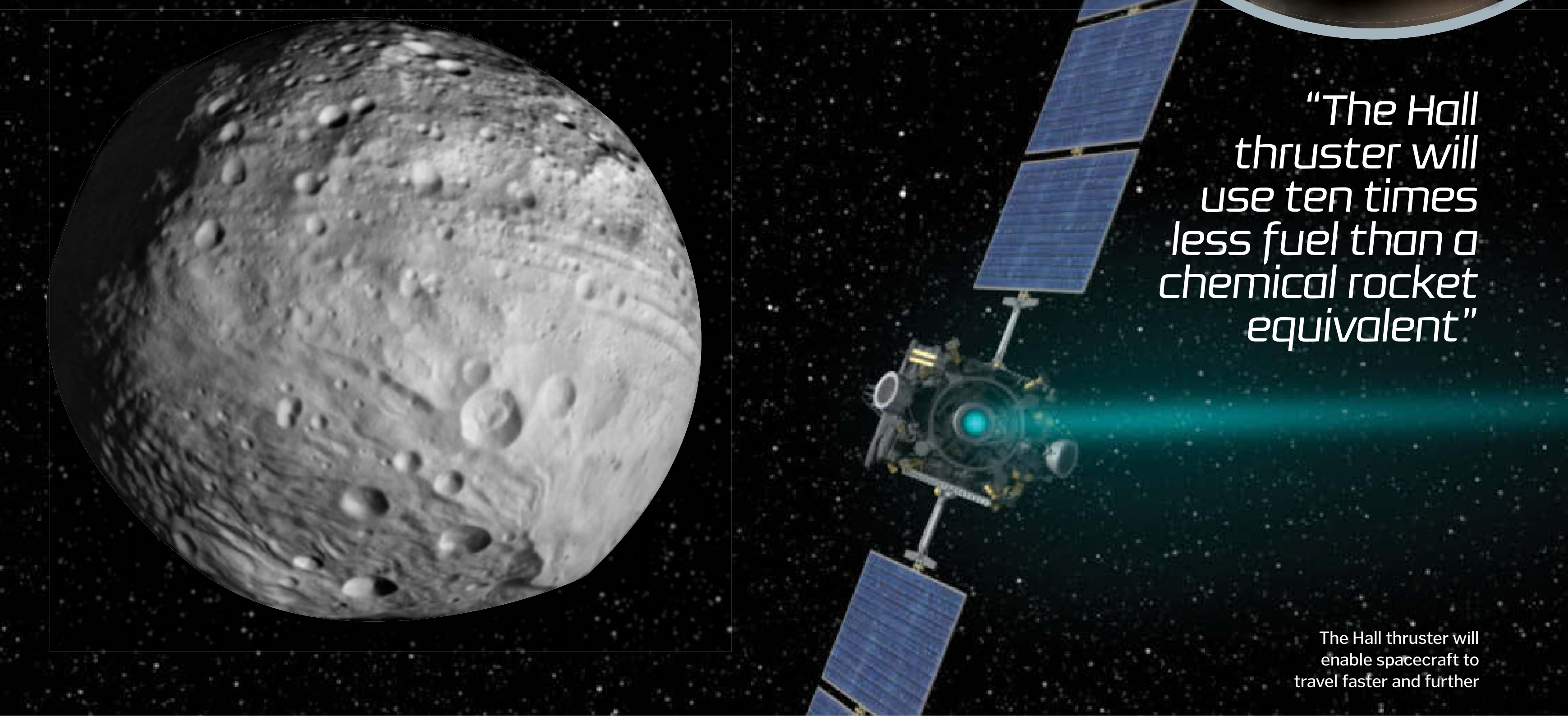
Hall thruster engines

Regular rocket engines work by the principle of Newton's third law of motion: every action has an equal and opposite reaction. By firing exhaust gases out from the rocket engine's nozzle, a reactive force is produced that pushes the rocket in the opposite direction. This method has been used since the earliest space flights, but is inefficient and not a feasible method of powering long-distance trips.

That's why NASA are working on a propulsion system that could overcome these problems. Engineers from the Glenn Research Center have developed a Hall thruster, a type of ion engine that will use ten times less fuel than a chemical rocket equivalent. It works by electrically charging the propellant (usually xenon gas), which then gets accelerated in an electric field so it is fired out from the engine at high speed, producing thrust. This method of space propulsion is safe, cost-effective and much more efficient; it is hoped that Hall thrusters will propel an asteroid-redirect mission in the 2020s.



Fitted with ion thrusters, NASA's Dawn spacecraft was able to visit the giant asteroid Vesta, and is currently at Ceres



"The Hall thruster will use ten times less fuel than a chemical rocket equivalent"

The Hall thruster will enable spacecraft to travel faster and further

Hybrid train technology

By combining a conventional diesel engine with an electric drive system, engineers from Rolls-Royce believe they can make trains more efficient. The Hybrid PowerPack includes the standard diesel engine and cooling system, but is also fitted with an additional electric propulsion module and an energy storage system. The latter produces a type of regenerative braking, which was first used in Formula 1 cars. The kinetic energy created when the train is slowed down can be recovered by an electric motor, and then stored in batteries to be used later, rather than being wasted. This is particularly useful for trains that frequently stop and start during their journey. In the first trials carried out in early 2015, this hybrid technology reduced fuel consumption by 15 per cent compared to a standard diesel journey.

The Hybrid PowerPack was extensively tested over six weeks, during which the train travelled 2,300km

The Super Yacht Sub

Explore life beneath the waves in this luxury submarine

The Super Yacht Sub 3 (SYS3) is a personal submersible that gives three passengers the chance to explore 300 metres below the ocean's surface. Measuring just 3.2 by 2.4 metres, this compact vehicle was designed to fit on board a super yacht.

Four powerful, electric thrusters propel the SYS3. Two of these are mounted at the rear of the sub, while the other two are mounted on the side, allowing movement in any direction. The power comes from a lithium-ion battery, which provides 21.6 kilowatt-hours to the thrusters and onboard operating systems. This enables the sub to reach a top speed of 2.8 knots (just over five kilometres per hour), both underwater and on the surface.

The submarine is steered using a unique, dual-joystick controller, not unlike those used for games consoles. As well as operating the sub, the controller has an important safety role. It features a 'dead man's switch', which must be pressed every ten minutes to prevent the sub from returning to the surface, acting as a constant check on the submarine's occupants. The SYS3 base model costs a bank-breaking £1.6 million ($2.4 million), but if you already own a super yacht, that's just a drop in the ocean!


The SYS3 can be driven at sea level as well as underwater

Exploring the oceans

See the features that help the submarine to function underwater

Safety
The safety buoy is automatically released when the sub dives, marking its position to anyone at the surface.

Single lifting point
The sub can be lifted from the top using only one cable, making it easy to retrieve from the water and return to the yacht's garage.

Underwater visibility
The sub's viewing window is made from acrylic, which withstands 3,600 tons of pressure when the vehicle dives to 300 metres.

Thrusters
Four thrusters allow the sub to move in all directions while underwater.

Power
The lithium-ion battery provides 21.6 kilowatt-hours of power, allowing the sub to dive for up to six hours on a single charge.

Controls
Operated mainly by the handheld controller, all other controls are kept away from the front to leave the underwater view unobstructed.

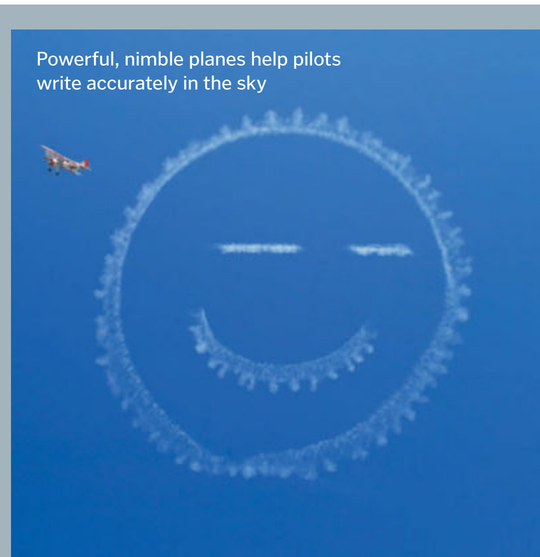
Writing in the sky

Learn how planes leave messages at 3,000 metres

By adding a paraffin-based oil into a plane's exhaust, thick, visible, white smoke is produced that can be used to graffiti the sky. This technique is mainly used for advertising, acting as an enormous, temporary billboard.

When the pilot is ready to start writing, they flip a switch in the cockpit, opening the reservoir containing the paraffin oil and releasing it into the plane's exhaust. The incredibly hot temperatures instantly vaporise the fluid, producing white smoke that pours from outlets at both ends of the plane. Once released, the smoke expands to a width of over 20 metres, making each letter visible from up to 50 kilometres away.

Pilots have to execute precise manoeuvres in small, powerful planes to write the letters accurately, while pressed into their seat by strong G-forces. The writing works best at altitudes of around 3,000 metres, as the cool air exerts more pressure on the smoke letters, holding them together and keeping them visible for longer.


Powerful, nimble planes help pilots write accurately in the sky

U-Boat Worx; Alamy

As the tyres wear down during the race, they can each lose around half a kilogram in weight

Mercedes F1 W06 hybrid

Winning almost every race, Mercedes' 2015 Formula One car owes much of its success to ingenious engineering

After this season's victory, Lewis Hamilton has now won three world championships, two with Mercedes

In 2014, the governing body of Formula One decided that it was time to introduce hybrid engines, and in doing so, changed F1 forever. The 2.4-litre V8 gas-guzzling monsters were replaced by the more economical, less noisy 1.6-litre V6 hybrid. The restrictions limited the amount of fuel the cars could consume, so it was a race to develop new technologies within F1.

World Championship winners, Mercedes AMG, created the PU106A/B Hybrid Power Unit with a turbocharger that uses waste energy from the exhaust to power the car's compressor – the part that draws in air at high pressure before it enters the engine. The internal combustion engine is powered by fuel, making it the traditional part of the hybrid engine. It consists of six cylinders arranged in a 'V' formation – hence the name V6 – and inside each one is a piston that moves as fuel in the cylinder is ignited. As the pistons move up and down, they drive a crankshaft, which in turn spins the car's wheels.

Whereas the crankshaft rotational speed of the V8 engines was up to 18,000 revolutions per minute (RPM), the V6 is limited to 15,000 RPM in accordance with the new F1 regulations. The reduction in speed, fuel capacity and number of cylinders means there is less friction so the car is more fuel-efficient. This, coupled with the energy-recovery technology of the turbocharger, means that F1 is now more relevant to road car research and development, according to Mercedes AMG.

STATS

WEIGHT:
702kg

HEIGHT:
0.95m

WIDTH:
1.8m

LENGTH:
5m

Mercedes' hybrid technology

As the age of the hybrid engine continues, Mercedes are constantly researching new ways to boost power and performance while remaining within Formula One's limits. The current engine produces the same power output as its V8 predecessors, but incredibly uses only two thirds of the fuel. It boasts a 40 per cent thermal efficiency compared to the 29 per cent achieved in Mercedes' previous models, which has led some to class this engine as the most efficient gasoline powertrain ever built.

Hybrid engine
The PU106 Hybrid Turbo is a 1.6-litre V6, capable of producing 15,000 RPM in its mid-mounted, rear-wheel drive format.

Prioritised safety features
The cockpit is fitted with a survival cell that features built-in, impact-resistant construction with sturdy penetration panels, as well as front and rear roll structures to protect the driver in a crash.

Immense cost
In material costs alone, the average F1 car is worth a staggering £1.7 million ($2.6 million). The steering wheel is worth more than your average family car, at around £50,000 ($77,000).

Tyres
F1 has used Pirelli tyres exclusively since 2011. There are six different models depending on race conditions, ranging from the slick super softs to treaded wets, which sit on magnesium forged Advanti wheels.

Chassis
The car's bodywork is made mostly of a carbon fibre composite, which is used for the engine cover, sidepods and the front and rear wings.

Front nose
The short nose of the W06 remains much the same as in its predecessor (the W05), with the addition of two sections on the underside, which improve airflow.

High-tech suspension
Both the rear and front suspension systems are fitted with carbon fibre wishbones, providing the most efficient and smoothest possible ride for the driver.

THE MARTIN JETPACK

HOW DOES THIS HIGH-FLYING GADGET TAKE TO THE SKIES?

Ever since they first made an appearance in science fiction films, real jetpacks have been promised by a number of different companies and inventors around the world. With its latest prototype, the Martin Aircraft Company believes it has mastered this long anticipated personal aircraft.

Despite the name, it isn't actually powered by a jet engine. Instead, this contraption relies on a 200 horsepower, V4 engine, fuelled by a mix of regular petrol and two stroke oil – much like old mopeds. This powers two carbon fibre fan ducts, one fitted to either side of the jetpack. Air is drawn in from above and accelerated using the fan's rotors, creating enough downforce to propel a payload of up to 120 kilograms to a height of around 900 metres.

The aircraft is made from sturdy, foam-filled carbon fibre, and can be piloted using two joysticks and a touchscreen, or flown from the ground via a remote control. It benefits from a fly-by-wire, semi-automatic system that helps to balance out the controls between the pilot and the onboard computer. Once airborne, the Martin Jetpack can fly for roughly 30 minutes, achieving a top speed of 74 kilometres per hour.

When this jetpack does eventually go on sale, it will retail in the region of £99,000 ($150,000). However, this won't just be reserved for gadget-loving millionaires. A number of emergency services are interested in using the jetpack; the Abu Dhabi fire service has already made a bulk order.

History's MOST GRUESOME inventions

From brutal torture devices to bizarre medical treatments, these terrifying contraptions reveal a darker side of innovation

From the wheel to the World Wide Web, we have invented some truly ground-breaking things during our time on Earth. Yet throughout history, inventors have also been known to put their skills to use in horrifying ways, creating contraptions that have caused unimaginable suffering.

In the past, if you committed a terrible crime, a punishment much worse than a long prison sentence awaited you. From boiling people alive to sawing them in half, execution methods were often developed to be as cruel as possible. These gruesome events were usually carried out in public to deter others from following in the footsteps of the accused.

Even if you weren't sentenced to death, there were plenty of ghastly implements that could be used to torture you instead. Typically used to extract a confession or information about accomplices, torture was popular in medieval times, with the screams of victims echoing from castle dungeons across Europe.

War has also inspired a wide selection of horrific innovations. While guns and bombs were designed to kill instantly, chemical weapons could draw out death for several agonising days – thankfully, this form of warfare is now prohibited.

We are also lucky that some medical devices from history are no longer used. Despite being designed with good intentions, many medieval procedures were truly stomach-churning, making a trip to the doctor quite the ordeal.

So as you drive around in your car and browse the web on your phone, be grateful that the inventions you use aren't gruesome like these…

The brazen bull

Turning the screams of the dying into the roar of a beast

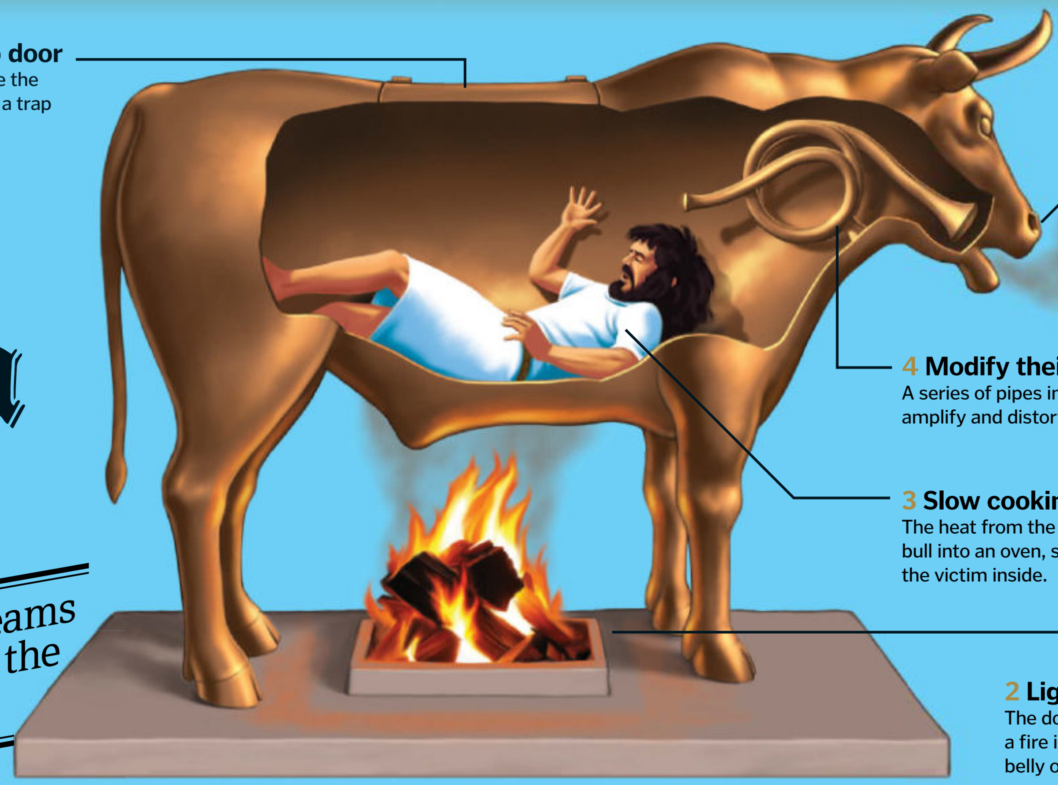


Illustration by Tom Connell / Art Agency

One of the most brutal methods of execution ever created took the form of a hollow bull statue. Invented in ancient Greece by Perillus, a bronze worker in Athens, it was given as a gift to a cruel tyrant named Phalaris of Agrigentum. As well as roasting criminals alive, the device also doubled as a musical instrument, converting the victim's desperate cries into what Perillus described as "the tenderest, most pathetic, most melodious of bellowings". Distrustful of the inventor's claims, Phalaris ordered Perillus to climb inside and prove the device's musical capabilities himself. However, as soon as he was inside, Phalaris shut the door and lit a fire beneath, causing Perillus to scream for real. However, rather then letting him die at the hands of his own creation, Phalaris had him removed and thrown off a cliff instead.

Crucifixion

Devised over 2,500 years ago as punishment for the most serious crimes, crucifixion would kill victims in a horribly drawn-out and painful way. With their wrists and feet nailed or tightly bound to a cross, and their legs broken by the executioners to speed up death, the victim's weight would be transferred to their arms. This would gradually pull the shoulders and elbows out of their sockets, leaving the chest to bear the weight. Although inhaling would still be possible, exhaling would be difficult and the victim would eventually suffocate due to a lack of oxygen. This excruciating process could take 24 hours.

Crucifixion would lead to suffocation and multiple organ failure

Louis XVI and Marie Antoinette were both publically executed using the guillotine

Guillotine

Although beheading methods had already been around for centuries, in 1789 French physician Dr Joseph Guillotin proposed a much more efficient and humane device for decapitation. When the executioner released the rope holding the guillotine's weighted blade in place, it would drop onto the victim's neck, killing them in a fraction of a second. This helped to eliminate the human error that was common with axe and sword beheadings, which sometimes required the executioner to deliver multiple swings to fully remove the head. Although quick, guillotine executions were popular spectator events during the French Revolution and the guillotine operators become national celebrities.

Electric chair

Electrocution was introduced as a quicker and supposedly less painful method of execution than hanging in the 1880s. When brought to the electric chair, a person has their head and one calf shaved to reduce resistance to electricity and is strapped in across their waist, arms and legs. A moistened sponge is then placed on their head and an electrode in the shape of a metal skullcap is secured on top. Another electrode is attached to their shaved leg and then the power is switched on. 2,000 volts pass through their body, paralysing the respiratory system and causing cardiac arrest.

Electrocution is still used as a method of execution in some US states

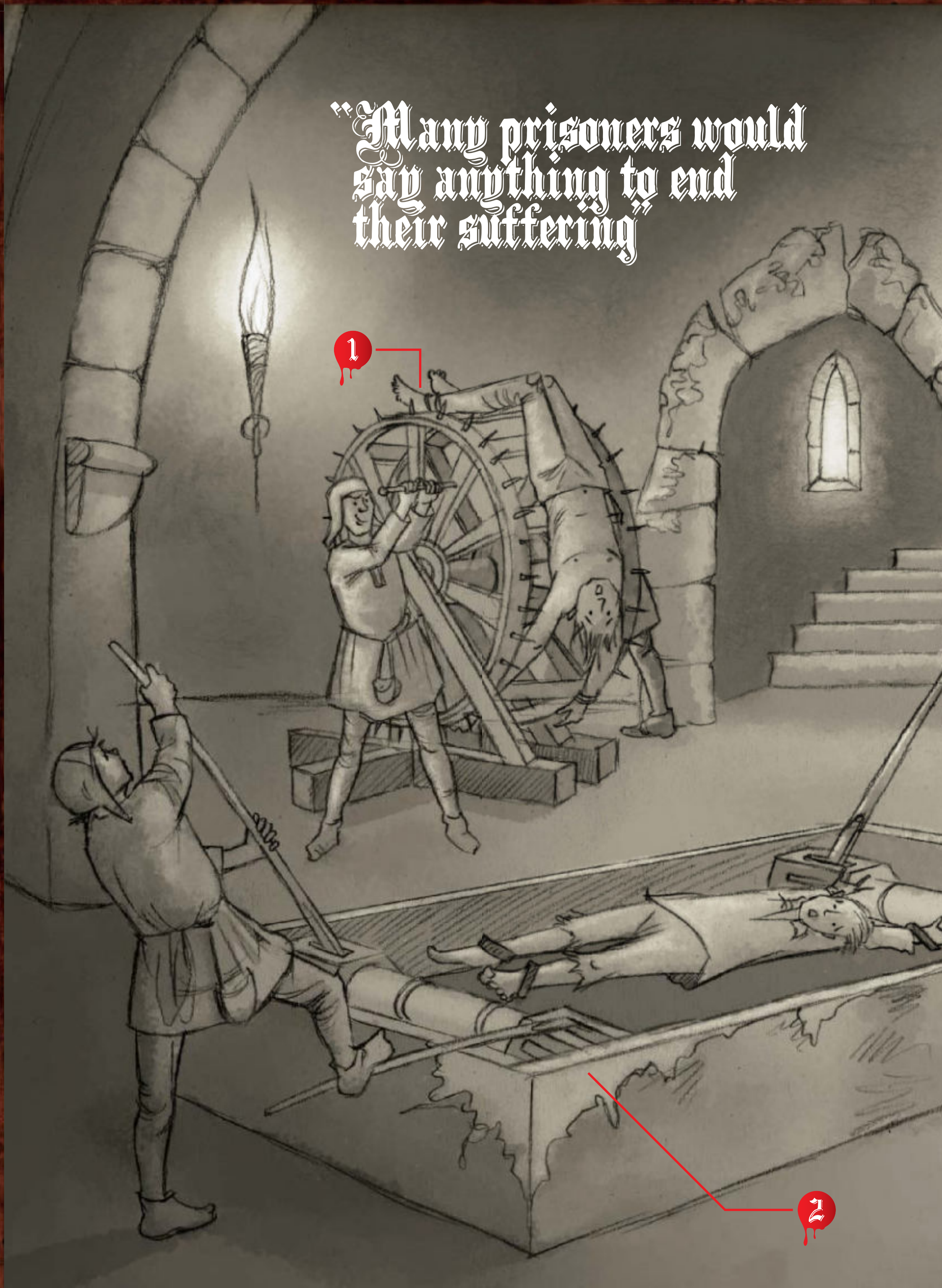
Inside a torture chamber

The terrifying devices that inflicted intense pain

Torture has been used as a method of punishment and interrogation for centuries, with the ancient Greeks and Romans regularly torturing criminals as part of their justice system. However, by the Middle Ages torture had become particularly prevalent, especially in response to crimes of treason. If you had been disloyal to the sovereign and your country, a whole plethora of horrifying torture devices awaited you.

Torture was usually conducted in secret, with most medieval castles featuring an underground dungeon in which these diabolical deeds took place. A great deal of ingenuity and artistic skill went into developing instruments that would inflict the maximum amount of pain. Often simply threatening to use one on a person was enough to get them to confess, while others would quickly give in after seeing it used on a fellow prisoner. Some torture devices were designed to only inflict pain, but others would result in a slow, drawn-out death that prolonged the suffering until the victim drew their last breath.

However, even if a prisoner was lucky enough to survive the torture, they were usually left severely disfigured and often had to be to be carried to their resulting trial, as they could no longer walk on their own. From the mid-17th century onwards, torture became much less common as there was much speculation about its effectiveness. Many prisoners would say anything to end their suffering, so it often produced inaccurate information or false confessions. It wasn't until 1948 that the United Nations General Assembly adopted the Universal Declaration of Human Rights, banning the use of torture.



1 Breaking wheel

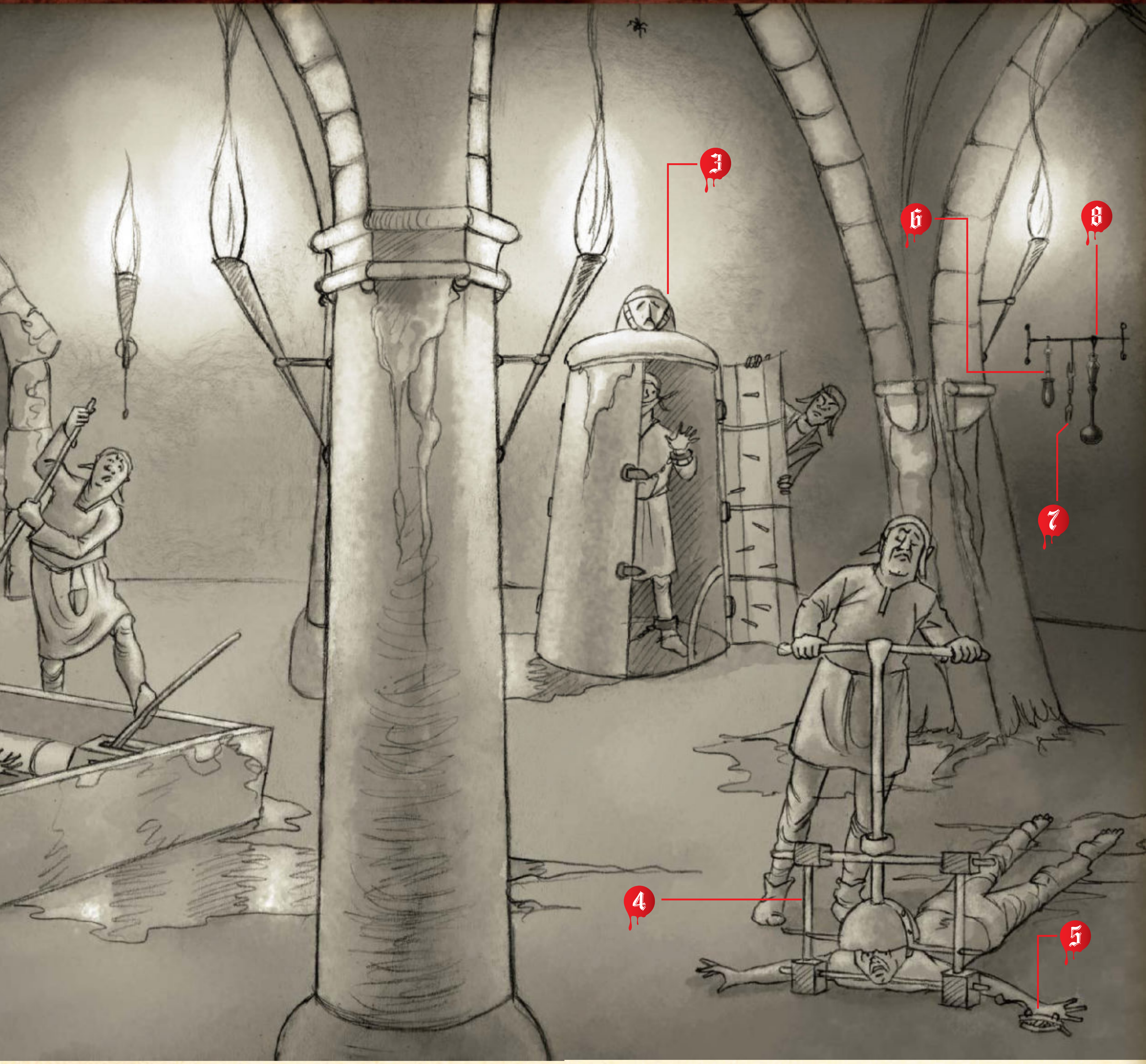
With the victim's limbs tied to the spokes of this large wooden wheel, it would be slowly revolved. As it spun, the executioner would bludgeon the victim's arms and legs with an iron hammer, shattering their bones one by one. If the victim survived this, they were placed on top of a large pole, so birds could peck at their body until they eventually died of dehydration, which could take several days.

2 The rack

With their hands and feet tied to rollers at each end of the wooden frame, the torture victim would be subjected to intense interrogation. If they failed to confess to their crimes or give up the information the torturer was looking for, a crank would be turned to rotate the rollers. This would pull on the ropes, gradually stretching the victim's body and causing intense pain, eventually dislocating their limbs.

3 Iron maiden

A series of menacing spikes protruded from the interior of this iron chamber. With the victim inside, the door was closed slowly, causing the strategically placed spikes to pierce their body. However, the spikes were not long enough to be instantly fatal. Instead, the victim would be left to slowly bleed to death.



4 Head crusher

With the victim's chin placed over the bottom bar and their head beneath the metal cap, the executioner would slowly turn the screw to bring the two together, only stopping if the victim gave the right answers. As the victim's head was crushed, their teeth would shatter into their jaw and their eyes would pop out from their sockets.

5 Thumbscrew

Used as punishment or a method of extracting information, the victim's fingers, thumbs or toes were placed between two horizontal metal bars. When the screw was turned, the two bars were pressed together, crushing the digits inside. Some thumbscrews even featured metal spikes on the bars to increase the pain.

6 Choke pear

Also known as the 'pear of anguish', this device was inserted into one of the victim's orifices, such as their mouth. When the key or crank was turned, the 'petals' of the pear-shaped end would slowly open up, painfully mutilating the victim's insides, but not causing death.

7 Heretic's fork

Usually reserved for blasphemers, this metal rod with two prongs at either end was attached to a leather strap around the victim's neck. One end would pierce their chin, while the other dug into their sternum, causing immense pain if they attempted to move their jaw or neck, making it more or less impossible to talk.

8 Lead sprinkler

Deceptively designed to look like a holy water sprinkler, this device was actually filled with molten lead, acid or boiling hot oil or water. The long handle was shaken to shower the victim's body with the substance inside. This caused horrific burns and was potentially lethal.

Miserable medicine

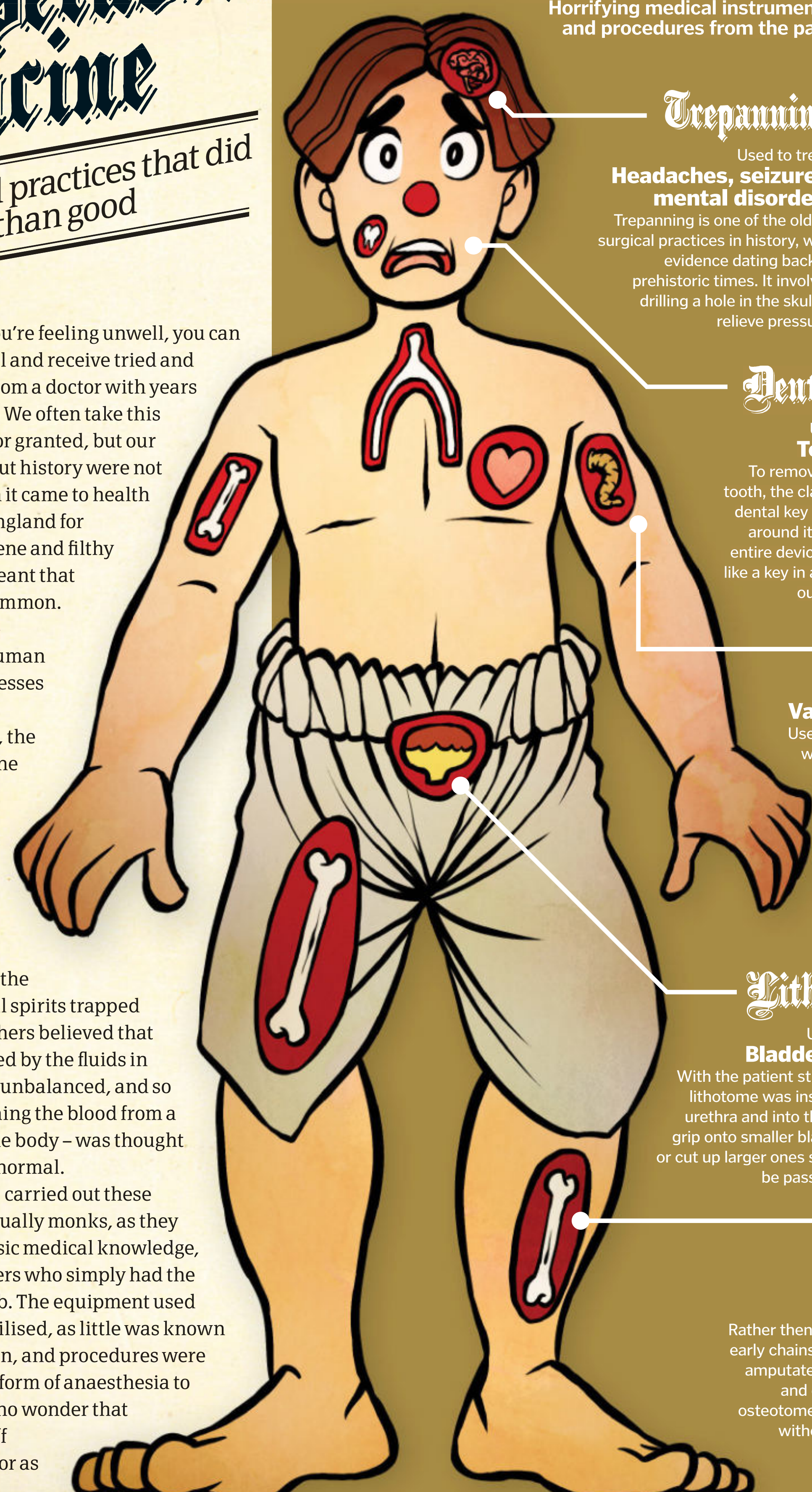
The medical practices that did more harm than good

Nowadays, when you're feeling unwell, you can visit a clean hospital and receive tried and tested treatments from a doctor with years of medical training. We often take this modern medicine for granted, but our ancestors throughout history were not quite so lucky when it came to health care. In medieval England for example, poor hygiene and filthy living conditions meant that disease was very common. However, with little knowledge of the human anatomy, many illnesses were attributed to witchcraft, demons, the will of god or even the positions of celestial bodies. Trepanning, which involves drilling a hole into the skull, was a popular treatment prescribed to allow the disease-causing evil spirits trapped inside to escape. Others believed that diseases were caused by the fluids in the body becoming unbalanced, and so bloodletting – draining the blood from a particular part of the body – was thought to restore things to normal.

The 'doctors' who carried out these procedures were usually monks, as they tended to have a basic medical knowledge, or barbers or butchers who simply had the right tools for the job. The equipment used was very rarely sterilised, as little was known about contamination, and procedures were carried out with no form of anaesthesia to numb the pain. It's no wonder that people would put off seeking treatment for as long as possible!

Terrifying treatments

Horrifying medical instruments and procedures from the past

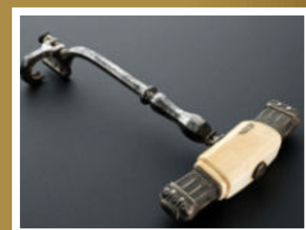


Trepanning

Used to treat:
Headaches, seizures, mental disorders

Trepanning is one of the oldest surgical practices in history, with evidence dating back to prehistoric times. It involves drilling a hole in the skull to relieve pressure.

Dental key



Used to treat:
Toothache

To remove a damaged tooth, the claw end of the dental key was clamped around it and then the entire device was turned like a key in a lock to lift it out of the gum.

Artificial leech

Used to treat:
Various infections and diseases

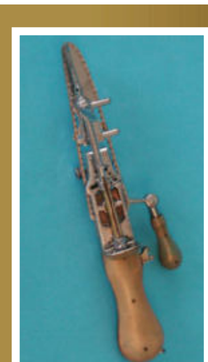
Used for bloodletting a popular treatment for a wide range of medical conditions, this device mimicked the action of reel leeches, with rotating blades that cut into the skin whilst a vacuum in the cylinder sucked out the blood.

Lithotome

Used to treat:
Bladder stones

With the patient still awake, the lithotome was inserted up the urethra and into the bladder to grip onto smaller bladder stones or cut up larger ones so they could be passed naturally.

Osteotome



Used to treat:
Infections in the arms or legs

Rather then cutting down trees, this early chainsaw was actually used to amputate limbs. Unlike a hammer and chisel, the hand-cranked osteotome could cut through bone without causing it to splinter.

Weapons of war

How the chemical arms race changed the face of conflict

Chemical weapons

On 22 April 1915, Germany shocked the world by launching the first large-scale gas attack in war. After waiting several weeks for the wind to blow in the right direction, German soldiers released clouds of chlorine gas near the enemy trenches in Ypres, suffocating the unprepared Allied troops. Although The Hague Convention of 1899 prohibited the use of poisonous weapons, Germany justified its actions by claiming that France had already broken the ban by deploying tear gas grenades in 1914. The chlorine gas attack kick-started a chemical arms race and by the end of World War I, around 50 different chemicals had been used on the battlefield. The most prevalent were chlorine, phosgene and mustard gas, which would result in slow and painful deaths if soldiers were exposed to large enough quantities. Eventually, gas masks were developed for protection, but chemicals such as mustard gas could still cause horrific blisters if they came into contact with the skin. Among the most devastating chemical weapons are nerve agents, such as sarin, which attack the nervous system. Even small concentrations can be lethal, killing in mere minutes.

Cl_2

Chlorine

Appearing as a pale green cloud with a strong bleach-like odour, chlorine gas reacts with water in the lungs to form hydrochloric acid. This damages the lung tissue, causing coughing, vomiting and eventually death.

$COCl_2$

Phosgene

This colourless gas with a musty odour reacts with proteins in the alveoli, tiny air sacs found in the lungs. This leads to fluid in the lungs and eventually suffocation, but the symptoms can take up to 48 hours to manifest.

$C_4H_8Cl_2S$

Mustard gas

With the odour of garlic, horseradish or sulphur, yellow-brown clouds of mustard gas cause chemical burns on the skin, eyes and respiratory tract, leading to large blisters, temporary blindness and shortness of breath.

$C_4H_{10}FO_2P$

Sarin

Colourless, tasteless and odourless, this gas blocks normal communication between nerves. The nerve signals become stuck 'on', and muscles are unable to relax. This can lead to spasms, paralysis and asphyxiation.

The Geneva Protocol

By the end of World War I, over 125,000 tons of poison gas had been deployed in battle. Although it was only responsible for less than one per cent of the war's total fatalities, the psychological terror it had inflicted on soldiers was immense. On 17 June 1925, seven years after the war had ended, the Geneva Protocol was introduced, prohibiting the use of chemical and biological weapons. 138 states have now signed the treaty.

38 states originally signed the Geneva Protocol to ban the use of chemical weapons

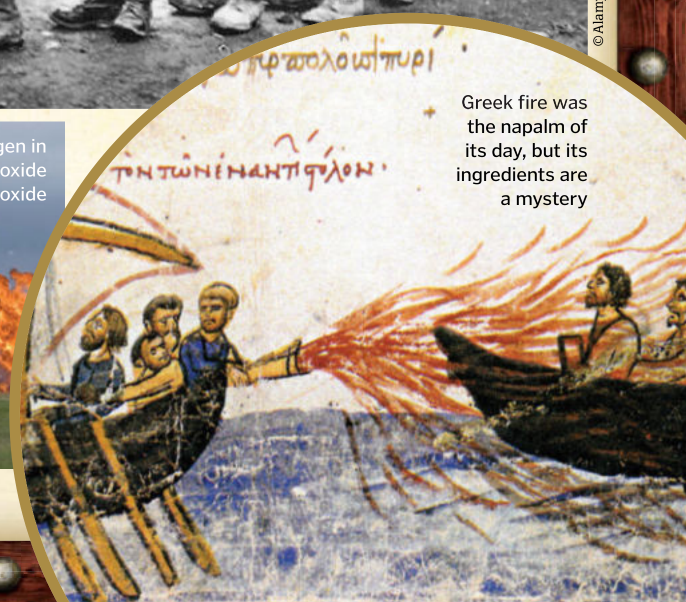
Napalm

Napalm is a flammable liquid with a gel-like consistency, allowing it to stick to surfaces easily. In a bomb, it is combined with gasoline or jet fuel to explode upon impact, capable of burning at more than 2,760 degrees Celsius. Even the slightest contact with skin can result in severe burns and it can also cause death by asphyxiation. When ignited, napalm generates carbon monoxide and removes oxygen from the air, suffocating those in the vicinity.

Napalm fires combust oxygen in the air, turning carbon dioxide into carbon monoxide

Greek fire

Developed by the Byzantine Greeks in the 7th century, Greek fire was a flammable liquid that could burn on water, making it particularly effective for naval warfare. This liquid fire was sprayed at the enemy using early flamethrower devices, or thrown in primitive hand grenades, creating a raging fire that could only be extinguished with sand, vinegar or urine. The true ingredients are a mystery, but scientists believe it could have contained petroleum, sulphur and pine tar.



Greek fire was the napalm of its day, but its ingredients are a mystery

How were Anderson shelters built?

These shelters protected millions during WWII

This Anderson shelter was left standing, even though many of the nearby buildings had been destroyed

Even before the outbreak of war in 1939 and the Blitz that followed, the British government realised the nation was vulnerable to air raid attacks. Free to those who earned less than £250 ($378) a year, the Anderson shelter was designed to protect up to six people from bombings, and was made of curved, corrugated steel sheets.

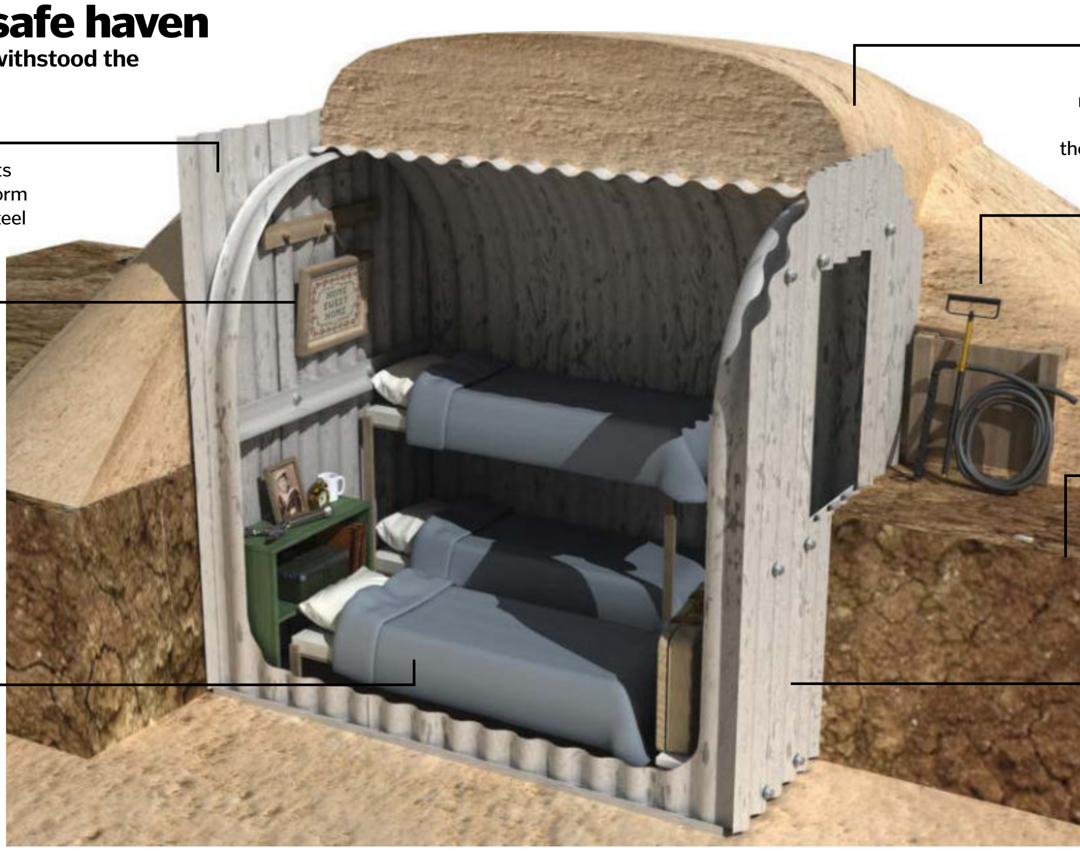
First, a shallow pit was dug in the ground, then the six steel sides were put in place and bolted together. Once complete, the shelter's roof was covered in a thick layer of earth. By the end of World War II, more than 3.5 million of these structures had been erected throughout the UK.

Due to their corrugation, these shelters stood up to nearby bomb blasts surprisingly well. The explosive force of a bomb would easily buckle flat metal sheets, but the curved structure of corrugated steel absorbed this energy without sustaining a huge amount of damage.

To prevent the shelters from rusting, their steel sides were coated in zinc, a process known as galvanisation. Zinc reacts more readily with oxygen, which means it rusts instead of the iron and the shelter's walls remain intact. As a result, some Anderson shelters are still standing, more than 70 years after the war ended.

Inside the safe haven

See the design that withstood the Blitz attacks



Iron panels
Six corrugated steel sheets were bolted together to form the shelter's walls, with steel plates at either end.

Decoration
This was kept to a minimum, although most Anderson Shelters were personalised with a few home comforts.

Cramped conditions
Six people were expected to pile into a single shelter, which left little room once the air raids began.

Protective cover
Soil, which had to be a minimum of 38 centimetres deep, was placed on top of the shelter to protect the roof.

Stirrup pump
The fire extinguishers of their day, these pumps could put out small fires with water.

Deep foundations
A 1.2-metre deep hole had to be dug for the shelter to go in, so that the walls and roofing wouldn't stick out.

Self-assembly
Supplied with only a flat pack kit, families had to build the shelters themselves.

Who invented the toilet?

Meet the man responsible for the first modern flushing toilet

Contrary to popular belief, the first man to invent the flushing toilet was not Thomas Crapper. It was actually a member of Queen Elizabeth I's court, Sir John Harrington.

First described in 1596, Harrington's device was composed of a deep oval bowl, which was made waterproof with a mixture of pitch, resin and wax. This was flushed with water released from a cistern above the toilet, on the next floor or in the roof.

In spite of this breakthrough, it took more than 200 years for the flushing toilet to catch on. Advances in technology that accompanied the Industrial Revolution helped to spur on the toilet's development, as did the invention of the 'S-trap' in 1775. Still present in modern toilets, this S-shaped pipe allows standing water to seal off the bowl, preventing gases from the sewer rising up and escaping into your bathroom.

One of Queen Elizabeth I's godsons, Sir John Harrington built the first flushing toilet in his own home

Anatomy of an American GI

The Vietnam War saw huge changes in uniform regulations

As the US involvement in the Vietnam War escalated in the 1960s, American troops were sent in to fight alongside the South Vietnamese soldiers against the communist North.

During this time, the US Army uniforms changed dramatically to meet the requirements of jungle combat. A lightweight, wind-resistant material called poplin was used to keep soldiers cool in the blistering Sun. This fabric also featured a threaded grid design that prevented it from ripping, while drawstrings around the trousers helped to keep creepy crawlies out.

Footwear also became an issue, as the standard leather boots started rotting away in the damp conditions. They were replaced by a hybrid boot, consisting of a leather bottom half and quick-drying canvas on the sides. Two drainage eyelets were included to help allow water escape and reduce the risk of a nasty condition known as jungle rot or trench foot.

The Vietnam War also saw the introduction of the ERDL camouflage pattern. The mixture of shapes coloured either brown, green, beige or black blended well with the jungle environment, and would go on to be adopted by numerous armies around the world.

Many of these innovations, along with the introduction of the M16 rifle, became vital to the soldiers who served in the Vietnam War, and some are still used today by the US Army.

Jungle combat

How US Army soldiers were equipped to fight through the challenging conditions

M1 helmet
Standard US Army issue since WWII, troops often customised their helmets with peace signs or playing cards.

Armour
The soldier's zip-up flak vests provided protection and a means of storing ammunition and grenades.

Utility belt
Fitted with a canteen and extra ammunition, these belts were heavy and cumbersome, but carried vital supplies.

Smoke grenades
The coloured smoke was used to provide cover, mark landing zones and identify the location of casualties.

M16 rifle
Replacing the heavy M14, this rifle was lightweight and produced a high rate of fire.

Combat clothing
Made of tightly woven fabric, the olive-green clothing provided camouflage and protection from all weathers.

Boots
A leather and canvas boots enabled the feet to breathe and water to escape through drainage eyelets.

The M16 rifle – hit or miss?

Initially, US soldiers were equipped with M14 rifles in Vietnam, but early confrontations with the enemy (who were using AK47s) showed that they were not appropriate for jungle combat – they were heavy, difficult to control, and used up ammunition too quickly.

American engineers set about designing a replacement: the M16. This gas-operated, automatic rifle was made of aluminium, steel and plastic, which was revolutionary at the time. It was capable of both fully automatic and semi-automatic firing, and could be modified to include a silencer. In 1966, the M16 replaced the M14, although it was not without its problems at first – there were reports of the rifle jamming during combat.

The M16 was easy to maintain, dependable and highly effective at close range

BRAIN DUMP

Because enquiring minds need to know...

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How It Works magazine @HowItWorksmag

howitworks@imagine-publishing.co.uk

MEET THE EXPERTS

Who's answering your questions this month?

Luis Villazon

Luis has a degree in zoology from Oxford and another in real-time computing. He builds steampunk gizmos and electronic gadgets, and his articles about science, tech and nature have been published around the world.

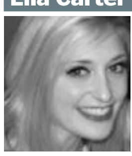
Laura Mears

Laura studied biomedical science at King's College London and has a master's from Cambridge. She escaped the lab to pursue a career in science communication and also develops educational video games.

Alexandra Cheung

Having earned degrees from the University of Nottingham and Imperial College London, Alex has worked at many prestigious institutions, including CERN, London's Science Museum and the Institute of Physics.

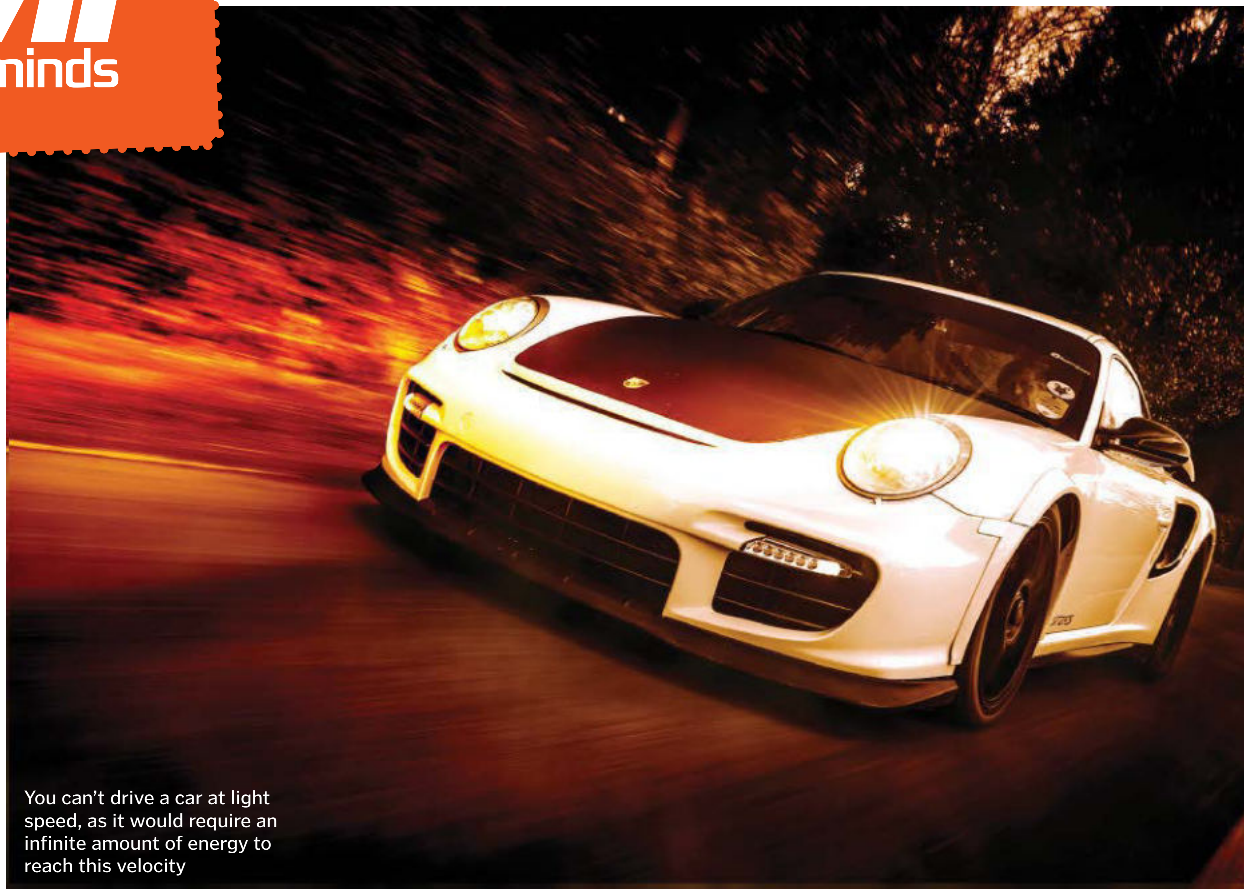
Ella Carter



Fascinated by the underwater realm, Ella studied marine biology and oceanography at university before embarking upon a career in publishing. She adores the natural world and loves researching and writing about the wonders within.

Shanna Freeman

Shanna describes herself as somebody who knows a little bit about a lot of different things. That's what comes of writing about everything from space travel to how cheese is made. She finds her job comes in very handy for quizzes!



You can't drive a car at light speed, as it would require an infinite amount of energy to reach this velocity

Would headlights work when driving at light speed?

Alfred Cross

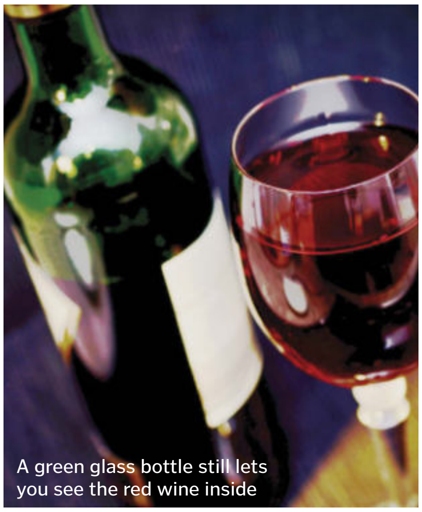
■ It's impossible for a car to travel at light speed. Einstein's special theory of relativity states that an object with mass cannot move at the speed of light. Your car would have to accelerate with an infinite amount of force in order to reach close to light speed, which of course couldn't ever happen. If we assume that a car could travel at almost the speed of light, though, the driver would not notice a difference because they would not be moving relative to the headlights. An analogy to help understand this is that fire engine drivers don't notice the pitch of their sirens changing as they are travelling, because relative to the source of the sound, they aren't moving. **SF**

In the industrialised world, women typically outlive men by five to ten years

Why do women usually live longer than men?

Alberto Benito

■ There is no definitive answer to this question, but the global spread of this disparity suggests that it is linked to our biology rather than to differences in lifestyle. One theory is that women's two X chromosomes mean that they have a spare copy of X-linked genes, providing a back up in case one malfunctions. Another is that lower iron levels brought on by menstruation protect women from cardiovascular disease. Alternatively, the male hormone testosterone may somehow shorten the life expectancy of men. This hypothesis arose from studies into eunuchs and sterilised men, who usually live longer than their testosterone-producing counterparts. **AC**



A green glass bottle still lets you see the red wine inside

Why are wine bottles usually green?

Elsy Millhouse

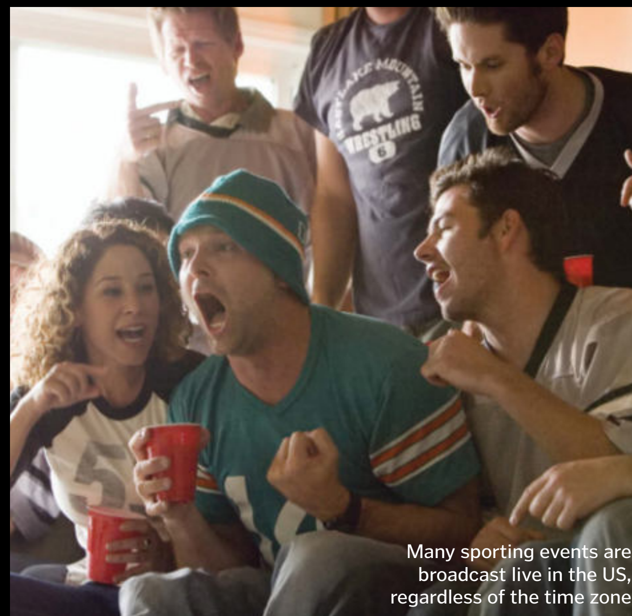
Wine bottles are commonly thought to be green because the colour protects the wine from the chemical changes caused by the ultraviolet (UV) wavelengths of sunlight. But this explanation doesn't stand up to scrutiny, because clear glass absorbs UV almost as well. What's more, white wine is more sensitive to light damage than red, yet is normally stored in clear bottles. Green glass is easier to make than clear glass, though, as many of the natural impurities already give glass a green colour. So it may be that green glass was originally used simply because it was cheaper and later became traditionally associated with wine. **LV**

How are TV shows scheduled in the US?

Alessia Bowen

The 50 states are covered by six time zones – Hawaii-Aleutian, Alaska, Pacific, Mountain, Central and Eastern. TV networks broadcast at least two separate 'feeds' to different time zones, where some are delayed so that they air at the right time in the right place. Eastern time is used as the default, followed by a time zone adjustment note, such as, "Tonight at 8/7 Central".

For live TV, networks can either tape-delay the broadcast, so that it still airs everywhere at say, 9pm, or show it live anyway – this is often the case for sports games. **EC**



Many sporting events are broadcast live in the US, regardless of the time zone

General anaesthetics disrupt nerve signals as they travel to the brain

How does anaesthesia work?

Kristen Wright

Anaesthetics prevent nerve signals from reaching the brain. Local anaesthetics block signals in just one area, while general anaesthetics affect the whole body.

Nerves send messages using electrical signals. For this to work, positively charged sodium ions need to move through channels on the surface of nerve cells. Local anaesthetics block these channels in a particular part of the body.

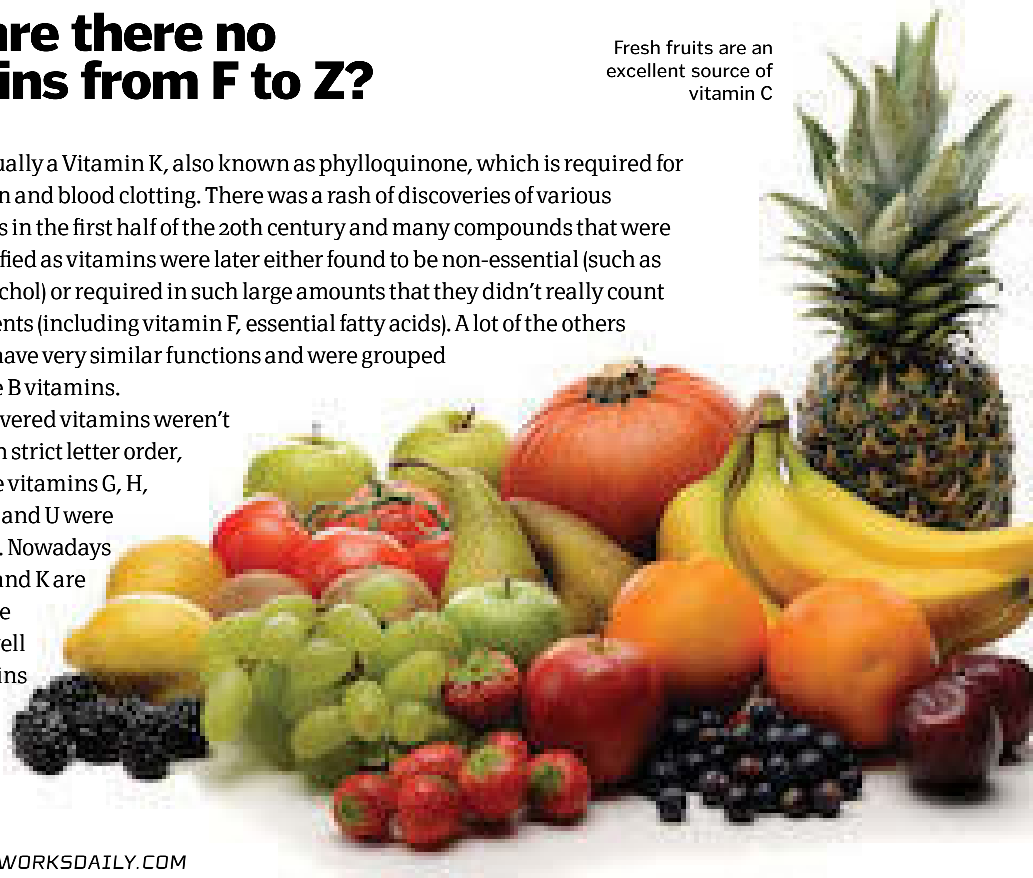
General anaesthetics work differently. Rather than blocking nerve signals, they disrupt them as they travel towards the brain. The mechanism for this is still unclear. **LM**

Why are there no vitamins from F to Z?

Meryl Pike

There is actually a Vitamin K, also known as phylloquinone, which is required for bone formation and blood clotting. There was a rash of discoveries of various micronutrients in the first half of the 20th century and many compounds that were initially identified as vitamins were later either found to be non-essential (such as vitamin J, catechol) or required in such large amounts that they didn't really count as micronutrients (including vitamin F, essential fatty acids). A lot of the others turned out to have very similar functions and were grouped together as the B vitamins.

Newly discovered vitamins weren't given names in strict letter order, but at one time vitamins G, H, L, M, O, P, PP, S and U were all recognised. Nowadays only A, C, D, E and K are counted as true vitamins, as well as the B vitamins from 1 to 3 and 5 to 7, plus B9 and B12. **LV**



Fresh fruits are an excellent source of vitamin C

FASCINATING FACTS

Is there anywhere on Earth with no life at all?

The only environments uncolonised by life are thought to be those with temperatures above around 150°C, such as inside deep sea vents, where proteins fall apart and chemical reactions cannot occur. **AC**

Some of the least hospitable environments on Earth are found inside deep sea hydrothermal vents

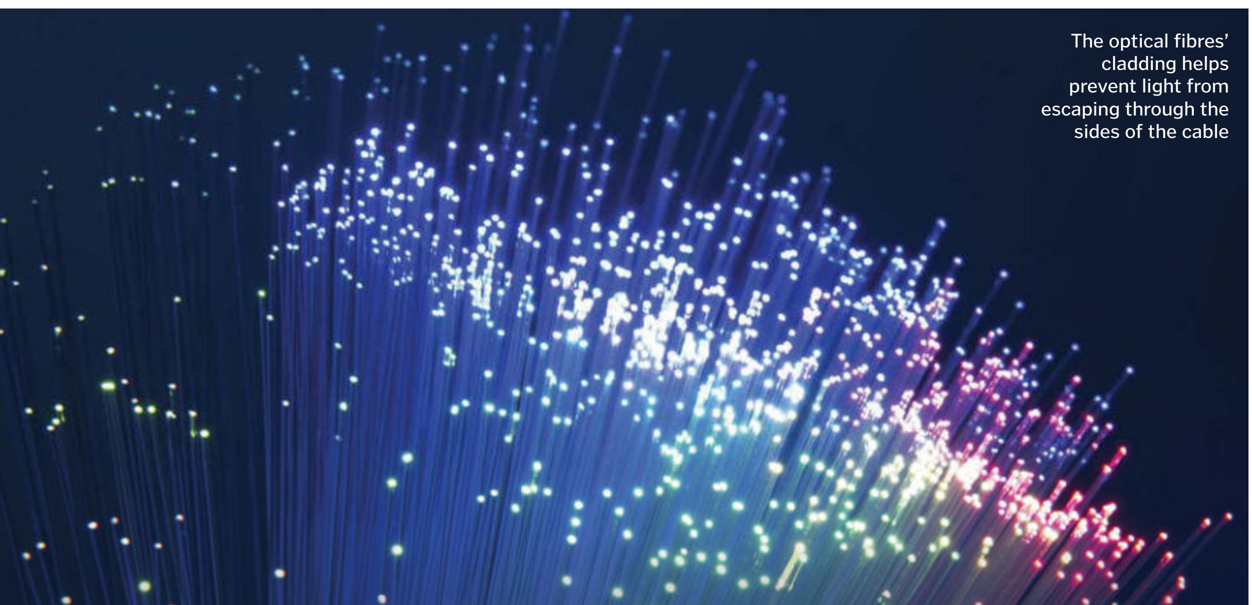
BRAIN DUMP

Bumblebees live in small nests, unlike the large, organised hives of their honey-making cousins

Do bumblebees make honey too?

Bo Underwood

The bumblebee is bigger, rounder and fuzzier than the wasp-like honeybee. Both bee types are crucial in the pollination of plants and crops and they both gather nectar to produce honey. However, the substance made by honeybees is produced in large volumes via a rather long-winded method, whereas bumblebees produce a more simplified 'honey' in small quantities. This is actually nectar that the queen bumblebee deposits into wax pots. She uses this to provide food for herself and her young. It is honey in the sense that it's produced by bumblebees from nectar, but it probably won't taste that good on your toast! **EC**



The optical fibres' cladding helps prevent light from escaping through the sides of the cable

How does light travel down a fibre optic cable?

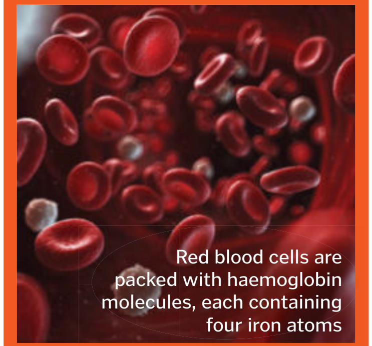
Dev Chandra

Fibre optic cables contain a core of very fine glass or plastic fibres, which are surrounded by plastic or glass tubes called cladding. Additional layers, including a buffer and jacket, protect the core from moisture and other damage. Light travels easily through the fibres, because their material has a higher index of refraction than the cladding. The differences in indices of refraction cause total internal reflection, which means that the light stays trapped in the core. Pulses of light sent through the cable carry data including sounds and images. Fibre optic cables are used in telecommunications, medicine, lighting and many other fields. **SF**

FASCINATING FACTS

How much iron is there in your blood altogether?

Adults have 12 to 17.5 grams of haemoglobin in every 100ml of blood, containing around 0.05 grams of iron. In the entire five to six litres of blood in your body, that adds up to around 2.5-3 grams. **LM**



Red blood cells are packed with haemoglobin molecules, each containing four iron atoms

What was the first national anthem?

There is some debate, but Japan is credited with having the first words to a national anthem, and the Netherlands lays claim to the first national anthem melody. **EC**

Japan's lyrics date back to the 9th century, and the Dutch melody was first used in 1572

What is the brightest star in the sky?

Other than the Sun, Sirius is the brightest star visible from Earth. Also called the Dog Star, it's actually a binary star system and is just 8.6 light years away. **SF**

Sirius A, captured by the Hubble Telescope with its tiny satellite Sirius B at the lower left

The salt in the Dead Sea crystallises on the shore into salt stalactites

How much salt is there in the Dead Sea?

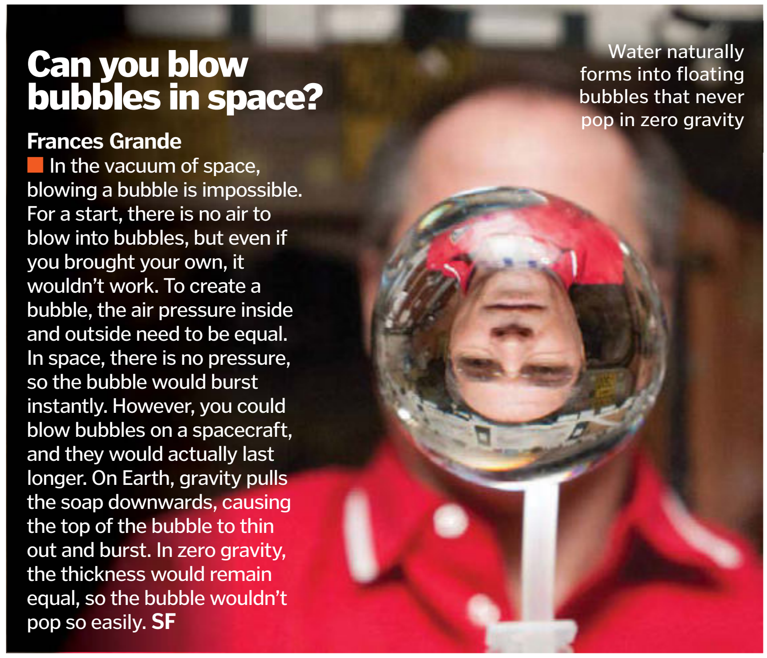
Loraine Schulz

The Dead Sea, which lies on the border between Israel and Jordan, has an average density of 1.24 kilograms per litre, allowing bathers to float in the salty solution. In the hot Sun, about 3.2 million litres of water evaporates from the lake every day, but less than that flows in from the river Jordan, or falls as rain, so the water is getting more concentrated over time. It currently has ten times the normal salinity of sea water, at 340g of salt in every litre. The volume of the Dead Sea is approximately 114 trillion litres, so it contains around 39 billion tons of salt! **LV**

Can you blow bubbles in space?

Frances Grande

In the vacuum of space, blowing a bubble is impossible. For a start, there is no air to blow into bubbles, but even if you brought your own, it wouldn't work. To create a bubble, the air pressure inside and outside need to be equal. In space, there is no pressure, so the bubble would burst instantly. However, you could blow bubbles on a spacecraft, and they would actually last longer. On Earth, gravity pulls the soap downwards, causing the top of the bubble to thin out and burst. In zero gravity, the thickness would remain equal, so the bubble wouldn't pop so easily. **SF**



Water naturally forms into floating bubbles that never pop in zero gravity

Why don't ballet dancers get dizzy?

Dominic Marcella

When a ballet dancer pirouettes, they don't rotate their head at a constant speed. Instead they will use a technique known as spotting, which reduces dizziness. They focus on a particular point as they turn, twisting their neck in the opposite direction to offset the rotation of their body. When the neck will twist no further, the ballet dancer snaps their head round quickly as far as it will go , to catch up with the body. This means that for most of the time, the dancer's vision isn't spinning, so their brain can maintain a nearly constant picture of the view ahead and they don't become disorientated. **LV**

Try looking at a fixed point if you're feeling dizzy!

Rats make high-pitched 50 Hz squeaks when they are tickled

Do animals laugh?

Max Cranley

Actually, they do. Researchers at Bowling Green State University, Ohio, showed that rats make high-pitched chirping sounds when tickled, and those that laugh more perform better in tasks that measure positivity. Tickling rats has also been found to reduce their stress levels. It might not be exactly like human laughter, but it seems pretty close. **LM**

Are snakes immune to their own venom?

Ken Cho

Most snakes have antibodies that act against their own venom, but they rarely need them since they're hardly ever exposed to it. Venoms are proteins, which exert their effect when they enter the victim's bloodstream. If a snake swallows some venom, its digestive system breaks down the toxic compound, rendering it harmless. Snakes produce venom in a specialised gland; the poison is then channelled into a duct leading to their fangs. Stored in this isolated chamber, the venom is prevented from spreading to other parts of the body or entering the circulatory system. **AC**

Snakes handle their own venom very carefully, limiting any exposure to themselves

BRAIN DUMP

Dogs may tilt their heads into a better position to aid their hearing

Why do dogs tilt their heads?

Abraham Chapman

■ Seeing an adorable dog tilt his head may be one of the cutest things to witness – it's as if your furry friend is a little confused. There are a few different theories as to what makes dogs do this.

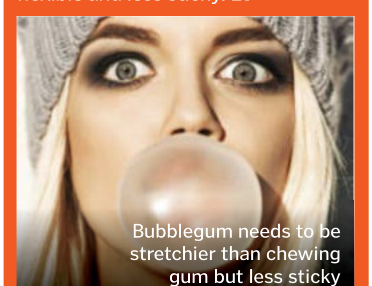
One explanation is that the dog rearranges his stance in order to better hear or see us. When a dog looks at you, their muzzle is blocking half of the view; cocking their head allows them to get a better look, especially at our faces, enabling them to adeptly judge emotional and physical clues from the way we act.

Another reason for the head tilt is that Fido knows we squeal with delight at his cuteness when he does it and shower him with love. Dogs cotton on to this very quickly, and as animals that are eager to please and bond with their owners, they will use it to their advantage! **EC**

FASCINATING FACTS

What's the difference between bubblegum and chewing gum?

Both types of gum use styrene butadiene, polyvinyl acetate and polyethylene as their base, but bubblegum has more corn syrup and vegetable oil to make it softer, more flexible and less sticky. **LV**



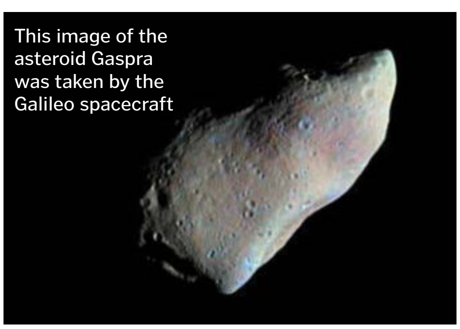
Bubblegum needs to be stretchier than chewing gum but less sticky

Why do some languages have male and female words?

Lara Carlos

■ Given the timescales over which language has evolved, and the absence of written communications until relatively recently, it's very difficult to determine why some languages have what's known as grammatical gender. Male and female nouns appear in about half of languages worldwide, and are particularly common in Indo-European tongues (including French, Russian and Hindi), suggesting that these languages evolved from an ancient language, Proto-Indo-European, that also used gender. In the case of Proto-Indo-European, linguists theorise that grammatical gender may have been used originally to distinguish between animate (male) and inanimate (female) objects, although this pattern is no longer visible. **AC**

Gendered nouns are common in Indo-European languages like French



This image of the asteroid Gaspra was taken by the Galileo spacecraft

How do spacecraft avoid asteroids?

Carmen Cruz

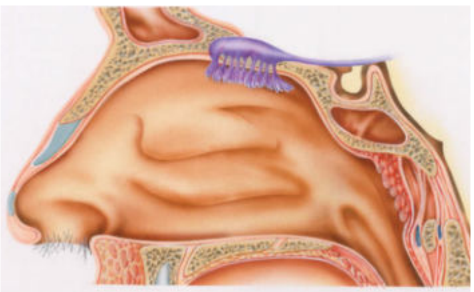
■ There's no way to be totally sure that a spacecraft won't collide with an asteroid, but it hasn't happened yet for a few reasons. We can track many asteroids, all the way down to ones that are just one centimetre in size, if they're in low-Earth orbit. And although we've identified more than 80,000 asteroids in the asteroid belt, we have a good sense of how they're distributed by size and it's not crowded out there. Finally, the trajectories of spacecraft are carefully planned out in advance, and small adjustments are made as necessary along the way. So other than collisions with tiny micrometeorites about the size of a grain of sand – which are considered normal wear and tear – the chance of running into an asteroid is very low. **SF**

Bubbles scatter light more effectively than liquid, giving them a lighter colour

Why do groups of bubbles appear white?

Elliot Bird

■ Bubbles absorb very little light. Instead, they reflect and refract the light around them in all directions, making them appear white or pale. A bubble is made up of a very thin wall of liquid with air or gas trapped inside. By contrast, a droplet of a similar size contains far more liquid, allowing it to absorb certain wavelengths of light and therefore appear coloured under white light. When you look at a single bubble it may appear colourless, but when they are sitting side by side in foam, light travelling through the bubbles is scattered in all directions, making them look white. In a glass of cola, the liquid contains pigments that absorb blue light but reflect green and red, making it look brown. However, the bubbles on top scatter all colours of light in all directions, resulting in a much paler colour. **AC**



Olfactory receptor cells (purple) are nerve cells responsible for detecting odour molecules

Why do we get used to smells?

Alan Brannigan

■ The medical term for this phenomenon is 'olfactory fatigue', and it's actually a really useful feature of the human body. We rely on the ability to pick out strange smells for survival. Odour molecules interact with specialist olfactory receptor cells inside the nose, triggering electrical signals that pass upwards towards the brain. But, like other sensory cells in the body, they will gradually stop responding, preventing the brain from being overloaded with a constant, repetitive signal. The brain itself also seems to be involved in filtering which incoming smell signals to take notice of, and which it can ignore. **LM**

Why don't we have two hearts or two livers?

Sharon Hardwick

■ The body is mostly symmetrical from the outside, but inside, not everything is mirrored. Beginning in the third week of pregnancy, the developing embryo goes through a process known as gastrulation, where it forms three distinct layers and starts to fold inwards to form a tube. This process gives us our left and right symmetry. After this, some organs, like the liver, grow from a single bud, resulting in one organ. Others, like the lungs, grow from a bud that splits in two, and some, like the kidneys, grow from two entirely separate buds. In our early development, we do have two hearts but these fuse together to make one heart with four chambers. The reason for the differences between these organs comes down to evolution – we don't need two hearts or two livers to survive. **LM**

We might look symmetrical on the outside, but inside it's a different story

Modern clock design was influenced by sundials

Why do clocks run clockwise?

Nathan Klein

■ Long before the conventional clock was developed, the Sun was used to discern the time of day. Pioneering ancient Egyptians were able to tell the time by looking at the shadow thrown by a gnomon onto a flat dial (a handy contraption that we now know as a sundial). In the Northern Hemisphere, as the Sun tracks across the sky, the shadow thrown by the gnomon appears to move in a clockwise direction. This design then directly influenced the design of the modern clock. Were clocks to have been first invented in the Southern Hemisphere, they would probably have been designed to run anti-clockwise, as this is the way the Sun appears to move. **EC**

New Brain Dump is here!

■ Don't miss issue 32 of **Brain Dump**, the digital sister magazine to **How It Works**, when it lands on the virtual newsstand on 7 January. Ever wondered who would win in a fight between a rhino and a hippo? You'll find out the answer to this question and more inside this jam-packed edition. You will also discover why spiders aren't classed as insects, whether elephants can jump and why reflections are reversed! Every edition is packed with stunning images and facts to impress your mates with. Download the new issue of **Brain Dump** every month from iTunes or Google Play. If you have a burning question, you can ask at **www.facebook.com/BraindumpMag** or Twitter – the handle is **@BrainDumpMag**.

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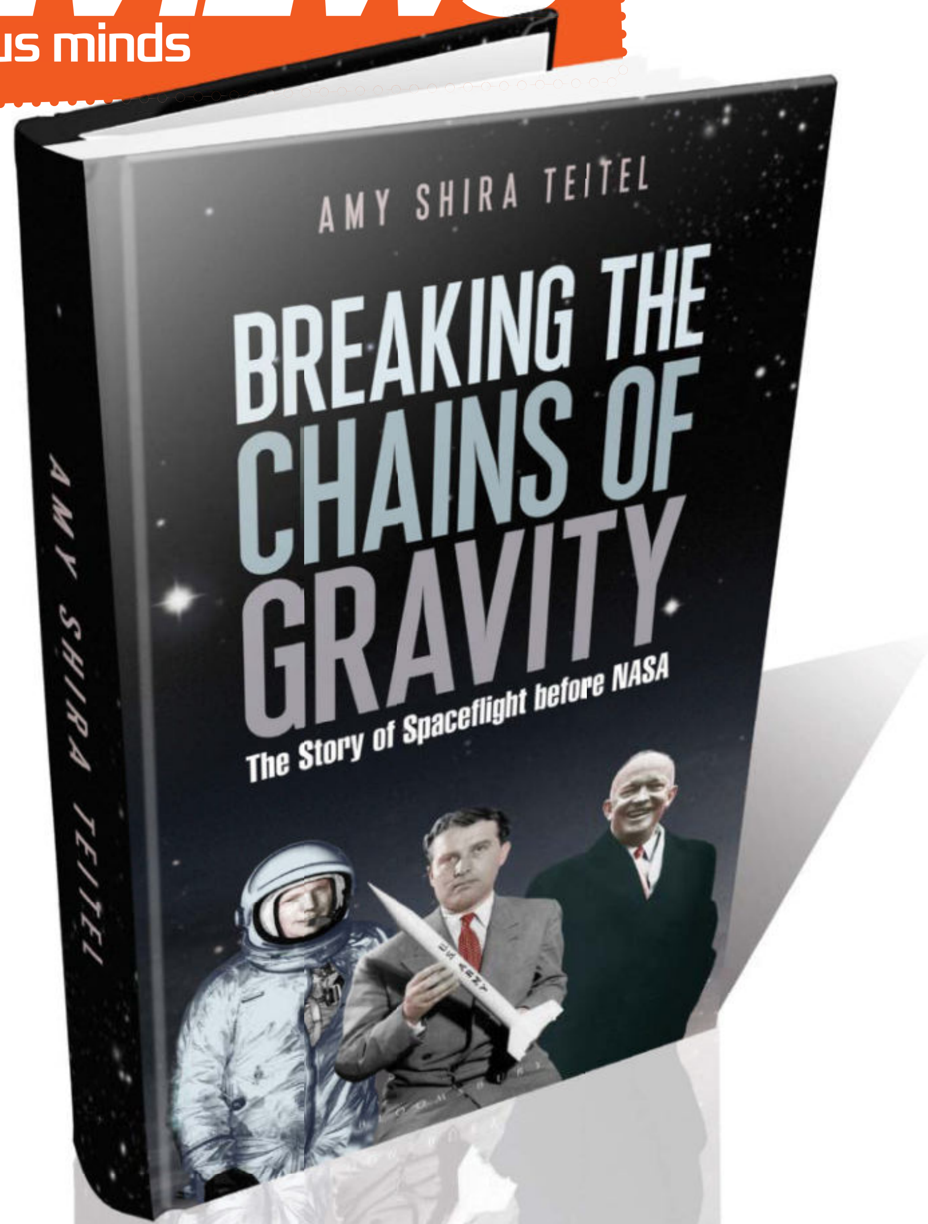
BOOK REVIEWS

The latest releases for curious minds



Breaking The Chains Of Gravity: The Story of Spaceflight before NASA

Explore the thrilling history that led to Neil Armstrong's small step

- Author: **Amy Shira Teitel**
- Publisher: **Bloomsbury Sigma**
- Price: **£16.99 / $27**
- Release date: **Out now**

The US national space agency has a long and famous history peppered with world-changing breakthroughs, but the story of what came before it is not so familiar. By the time NASA was established by President Eisenhower in 1958, non-Soviet scientists had already made great progress in building rockets to travel beyond Earth's atmosphere.

In her debut book, Amy Shira Teitel tells the story of the characters, rivalries and scientific breakthroughs that led to the agency's creation, and does so in a wonderfully engaging way. In the prologue, Teitel writes: "Spaceflight is part of our shared human history and shouldn't be an opus accessible only to initiates. It should be available to everyone interested in exploring this rich history". In the pages that follow she relays the space agency's thrilling backstory in a way that even non-space-nerds will find fascinating.

The book begins with the explosive rocket tests carried out by German scientists in the 1930s, paving the way for the world's first rocket, used to devastating effect in World War II. After the war, the focus shifted from weaponry to spaceflight and the space race between America and Russia quickly gained pace, inspiring a range of outlandish theories and innovations that went on to make spaceflight possible.

As a popular blogger about all things space, Teitel's enthusiasm for the subject is palpable on every page. A fantastic use of description helps to draw you into the story and really experience the events that shaped space travel for yourself. Interesting details and facts are woven into the main narrative, which delivers an easy and entertaining read that isn't bogged down with technical jargon. Those who want some extra nuggets of information can find an extensive glossary of people, places and organisations at the back, as well as a detailed bibliography.

Breaking The Chains is by no means a comprehensive guide to pre-NASA spaceflight – as Teitel admits, she had to simplify the story to reach a broader audience. However, by focusing on a few quirky characters and their dramatic stories, she has created a gripping book to rival big screen blockbusters.

YOU MAY ALSO LIKE…

Mission Control: Inventing the Groundwork of Spaceflight

Author: **Michael Peter Johnson**
Publisher: **University Press of Florida**
Price: **£22.50 / $24.95**
Release date: **Out now**

Telling the story of the people who guide rovers and astronauts from Earth, this book looks at the three major centres that have managed some of the most historic space missions.

Go, Flight! The Unsung Heroes of Mission Control

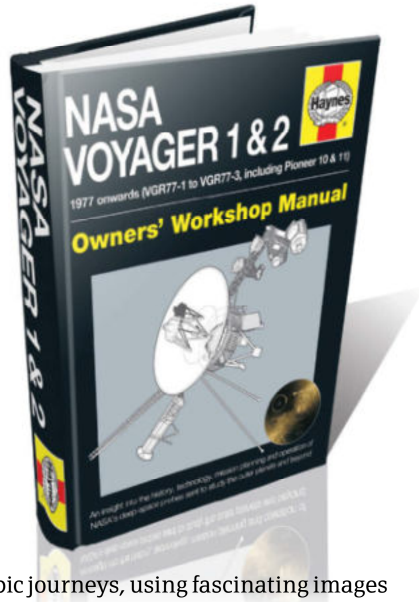
Author: **Rick Housten & Milt Heflin**
Publisher: **University of Nebraska Press**
Price: **£24.99 / $36.95**
Release date: **Out now**

A people's history of spaceflight, told through interviews with the talented men and women in mission control who made many of NASA's most important accomplishments possible.

Spaceshots and Snapshots of Projects Mercury and Gemini

Author: **John Bisney**
Publisher: **University of New Mexico Press**
Price: **£40.95 / $45**
Release date: **Out now**

A collection of hundreds of unpublished and rare photographs from both public and private sources tell the fascinating story of NASA's early space missions, before Apollo and the historic Moon landing.



NASA Voyager 1 & 2 Manual

Under the hood of the long-serving deep-space probes

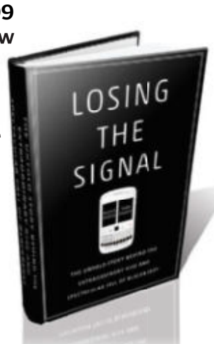
- Author: **Christopher Riley, Richard Corfield, Phil Dolling**
- Publisher: **Haynes Publishing**
- Price: **£22.99 / $36.95**
- Release date: **Out now**

Haynes Manuals are well-known for their practical, illustrated guides to maintaining and repairing cars and motorcycles, but this new release looks at some more out-of-this-world vehicles. Voyager 1 and 2 were launched in 1977 and have since travelled billions of kilometres to escape our Solar System and explore further into deep space than ever before. This book celebrates their epic journeys, using fascinating images and technical drawings to detail how the missions and the probes themselves work. Some of the artwork is a little tricky for engineering novices to understand, but the text does well to convey the amazing story of these long-serving craft. There's also an excellent guide to the contents of the Voyagers' famous Golden Record time capsules.

Losing The Signal

The rise and fall of BlackBerry

- Author: **Jacquie McNish, Sean Silcoff**
- Publisher: **Random House Business Books**
- Price: **£18.45 / $27.99**
- Release date: **Out now**

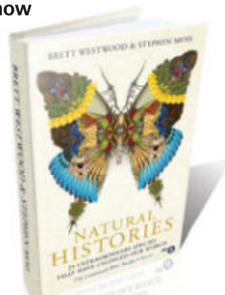


At its peak, BlackBerry controlled half of the US smartphone market, yet only six years later this number has fallen to less than one per cent. Here, the authors narrate the incredible rise and fall of the mobile phone company, focusing on the stories of Mike Lazaridis and Jim Balsillie, who turned their dream of wireless email into reality. Although based entirely on fact, the novelised style makes the book a compelling read. It details BlackBerry's humble beginnings above a bagel store, how it became the world's fastest growing company, and why everything fell away so spectacularly. It's hard to criticise the content or the style of this surprisingly entertaining book.

Natural Histories

The wonders of wildlife

- Author: **Brett Westwood, Stephen Moss**
- Publisher: **John Murray**
- Price: **£25 (approx $37)**
- Release date: **Out now**

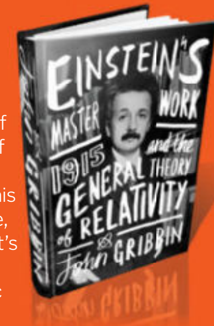


Written to accompany the BBC Radio 4 series of the same name, *Natural Histories* details the relationship we have with 25 wildlife species, from sharks and lions to brambles and coral. It explores the history, biology and cultural importance of each, explaining how they have changed our understanding of the world around us. The facts about lesser-known species, such as sea anemones, are a highlight; in many ways they bring more to the book than the chapters on big hitters like dinosaurs. It's probably a little heavy-going for younger readers, but it will make you appreciate the incredible natural world that surrounds us.

Einstein's Masterwork

The story of a scientific hero

- Author: **John Gribbin**
- Publisher: **Icon Books**
- Price: **£10.99 (approx $16.50)**
- Release date: **Out now**

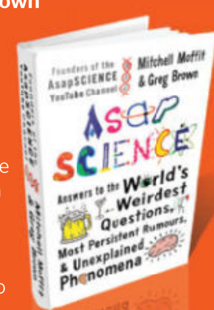


Einstein transformed our understanding of time and space with his General Theory of Relativity. But how much do you know about the man behind the moustache? This book offers an insight into his personal life, rise to fame and contribution to science. It's entertaining and accessible, also giving a glimpse into Einstein's incredible scientific work. Some readers may be disappointed with the lack of detail on his theories, but there are already plenty of books fulfilling that role. What acclaimed science writer John Gribbin brings to the shelves, however, is an entertaining mix of biography-meets-science-lesson. What better way to celebrate the 100th anniversary of Einstein's famous theory?

ASAP Science

Your weird questions answered

- Author: **Mitchell Moffit and Greg Brown**
- Publisher: **Scribner**
- Price: **£14.99 / $23.99**
- Release date: **Out now**



From the founders of the AsapSCIENCE YouTube channel, this book answers curious questions that most of us will have pondered from time to time, ranging from why we get pins and needles to why we hate photos of ourselves.

The design echoes the author's online videos, using funny cartoon illustrations to explain difficult theories. It's the sort of book that appeals to people of any age, and you'll never be short of dinner conversation topics with this in your collection. The book isn't quite as slick as the YouTube channel (if you've watched any of their videos you'll miss the witty presenting and clever animations), but it's still immensely fun.

Thing Explainer

1,000 words to explain everything

- Author: **Randall Munroe**
- Publisher: **John Murray**
- Price: **£16.99 / $24.95**
- Release date: **Out now**

Thing Explainer aims to show how both simple and complex objects work, from the nuclear bomb to the ballpoint pen. The detailed, blueprint-style diagrams throughout are the book's greatest feature, helping readers of any age understand how each part of a complicated item contributes to its overall function.

The author deliberately limited his vocabulary to 1,000 words when writing the book, and although this keeps everything simple to the extreme, it does get a bit annoying at times – why write 'sky boat' when everyone understands airplane? Having said that, you can't fault Munroe's determination to explain how things work to any reader. You'll just need to get used to knowing what something does rather than what it's called.

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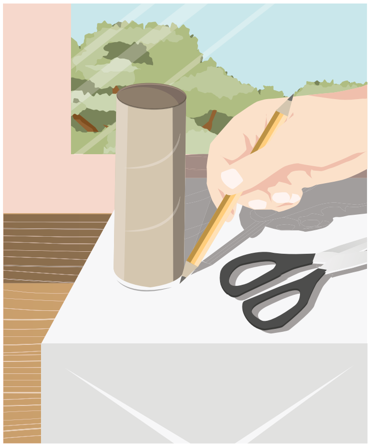
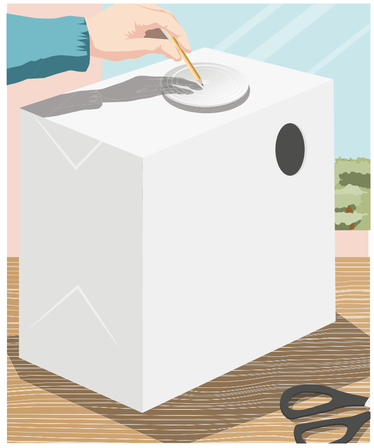
Build a spectroscope

With the help of diffraction, you can reveal light's rainbow of colours



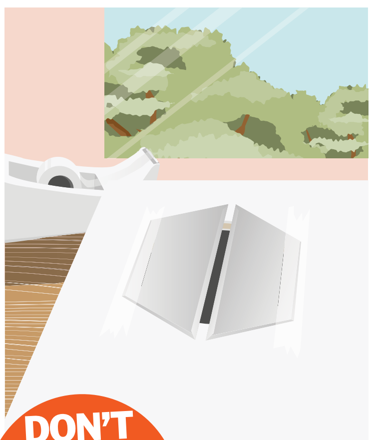
1 Make a viewing hole

Place a CD on one side of a box just over a centimetre from the box's edge, and draw around the circular gap in the centre of the CD. Centre your cardboard tube over this circle and draw around its edge, then move it slightly to the right and repeat the process. This will create an oval, which you can cut out using scissors. It needs to be wide enough for the tube to fit in at an angle.



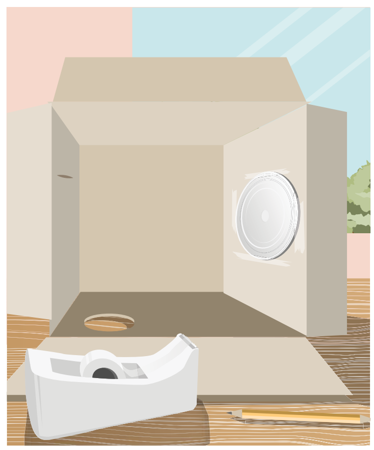
2 Position your light slit

Place the box flat on the table so that the oval you've just cut is on the side facing you. Take the CD and place it in the top left-hand corner of the side facing the ceiling, and draw around its central gap to show its position. Cut a small rectangle roughly 0.5 centimetres wide and 2.5 centimetres tall, with its base in line with the bottom of the circle you've just drawn.



3 Install your light slit

To create your light slit you should ideally use two razor blades, but if you can't get hold of these or you aren't comfortable handling them, use two business cards or two cardboard rectangles. Set the edges of the two blades over the hole you cut in Step 2, leaving a very small gap between them that is the same width at both ends. This will ensure that the light diffracts (splits apart) evenly when it enters the slit.



4 Tape down your CD

Next, you need to tape your CD to the inside of the box, on the opposite edge to your light slit. Its edge must be the same distance from the box's edge as the slit, so measure this with a ruler beforehand. Place the CD with the shiny surface pointing towards the light slit; this will reflect the light to the viewing tube. The box must be completely light tight, so cover the edges and any gaps with aluminium foil.

DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU

5 Complete the assembly

Insert your cardboard tube into the first hole you made, angling it towards the CD. Perform a test run before you tape it in place by pointing the slit towards a light source and checking that you can see the full spectrum of light through the tube. When you're happy with the results, complete your spectroscope by taping the tube securely to the box. Now you are ready to tell the difference between different light sources by examining their spectrum of light!

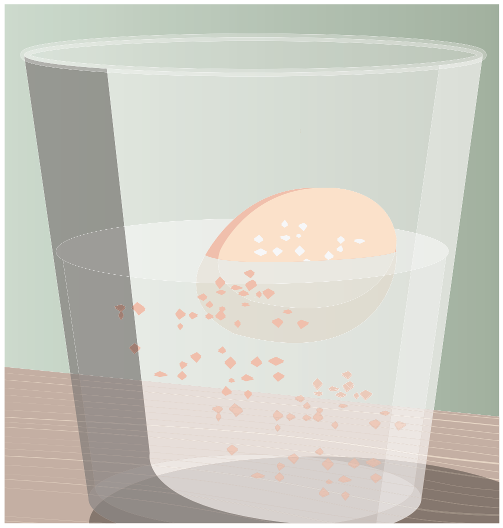
In summary...

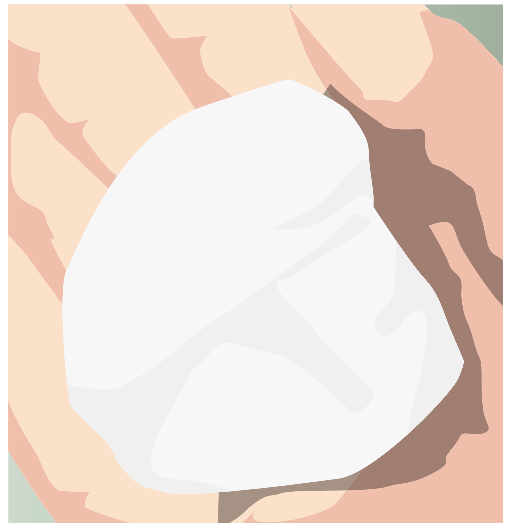
White light is made up of wavelengths ranging from red to violet, producing a continuous band of colours when viewed through a spectroscope. The viewing slit diffracts the light into different wavelengths, which reflect off the CD and into the eye. Try comparing a flashlight and a candle!

NEXT ISSUE
- Make hot ice
- Brew your own beer

Make a foldable egg

Extract an egg's inner membrane and inflate it like a balloon!





Illustrations by Edward Crooks

1 Remove the raw egg

The first step is to remove the raw egg without causing too much damage to the internal membrane. Hold the egg over a bowl, and use something sharp like a skewer to make a hole in either end. The hole at the bottom should be larger. Then break up the egg's yolk and use a drinking straw to blow through the small hole; the air pressure should expel the liquid egg. Run a little water through the empty egg to make sure it's clean.

2 Dissolve the shell

To remove the eggshell, you'll need to dissolve it in vinegar. Pour roughly 400 millilitres of vinegar into a glass jug and add the egg. Using your fingers, gently push the egg under the liquid until all of the air inside has escaped. It may take several minutes for the air to stop bubbling out, so be patient and make sure it's empty. Leave the egg in the vinegar for several days, in which time the shell should completely break away from the egg and dissolve.

3 Inflate the membrane

You will be left with a rubbery substance known as the egg membrane. Rinse it in water, gently squeeze to remove the excess and then dry it carefully with a paper towel. Once it's dry, pass it between your hands until it starts to fill with air. Eventually, it will expand like a balloon! Once inflated, sprinkle talcum powder all over the outside and try to get some on the inside if possible. This will prevent the sides from sticking together, helping it to inflate easily next time!

In summary...

The acetic acid within the vinegar breaks down the solid calcium carbonate eggshell, leaving the egg membrane. This is a hugely important part of the egg; its flexibility and durability allow the membrane to expand as the chick grows, while also keeping it safe. The membrane contains keratin, the same protein that is found in our hair and nails.

WIN!

Five K'NEX Thrill Rides Sets

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What is the name of the machine used by engineers to tunnel through rock?

a) **Tunnel-boring machine** b) **JCB**
c) **Underground tunnel driller**

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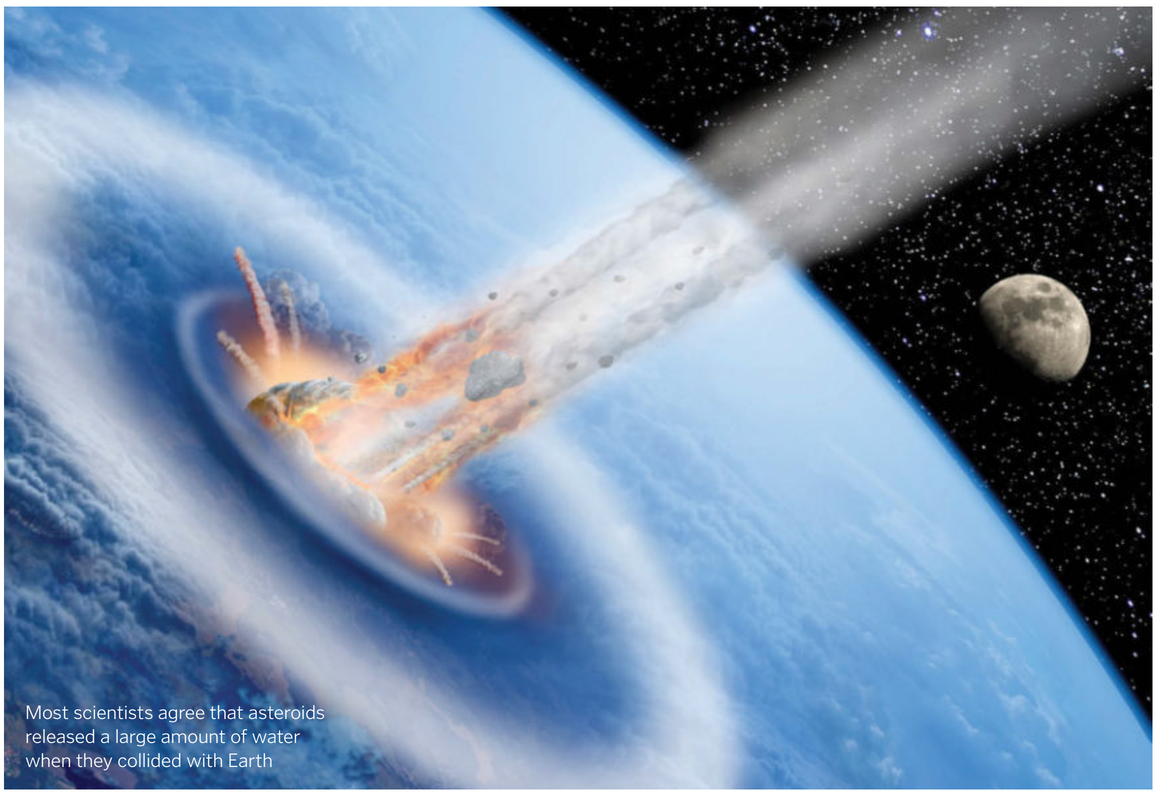
Letter of the Month

How did our oceans form?

Dear **HIW,**
I have a question for you to answer. How did Earth's huge oceans form millions of years ago?
Thanks,
Noor Al-ossmi (aged 9)

Today, water covers roughly 71 per cent of the Earth's surface. It's thought that Earth's oceans have been present for roughly four billion years, driving the climate and controlling the evolution of life itself. When our planet was born around 4.5 billion years ago it was a molten rock, far too hot for liquid water to exist on its surface. When the first volcanoes began to erupt they released steam, which formed enormous clouds as the planet began to cool. These clouds are thought to have given the planet its first rainy season; precipitation poured from the sky, possibly for thousands of years, delivering some of Earth's water.

However, most of our water was provided by a different source altogether. During Earth's early years, the planet was continually bombarded with asteroids, which can contain ice. It is believed that when they collided with Earth, they released this ice, eventually providing a huge amount of water for our planet's surface.



Most scientists agree that asteroids released a large amount of water when they collided with Earth

Up, up and away

Dear **HIW,**
I really enjoy your magazine and I think it's by far the best in the whole world! I was watching a hot air balloon the other day and would love to know, how does it work?
Thanks,
Will Rees (Age 12)

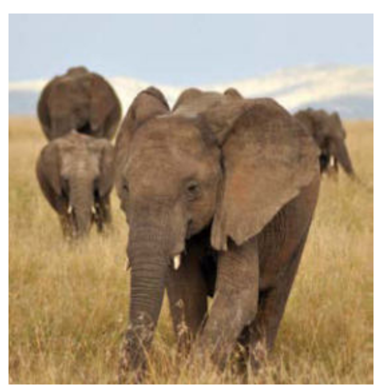
Thanks, Will! Hot air balloons rely on the principle that hot air is less dense than cold air, and therefore warmer air floats above cooler air. To take off, modern balloon burners use propane gas to heat the air within the large fabric balloon, which is called the envelope. Once the air is hot enough, the balloon lifts the basket containing the passengers from the ground, commencing the flight. Steering is difficult; the pilot needs to find wind that's blowing in the right direction and use it to their advantage. To land, a valve at the top of the balloon is opened, allowing hot air to slowly escape, reducing the altitude gradually.

Hot air balloons float because the hot air inside the envelope weighs less than the same volume of cold air outside

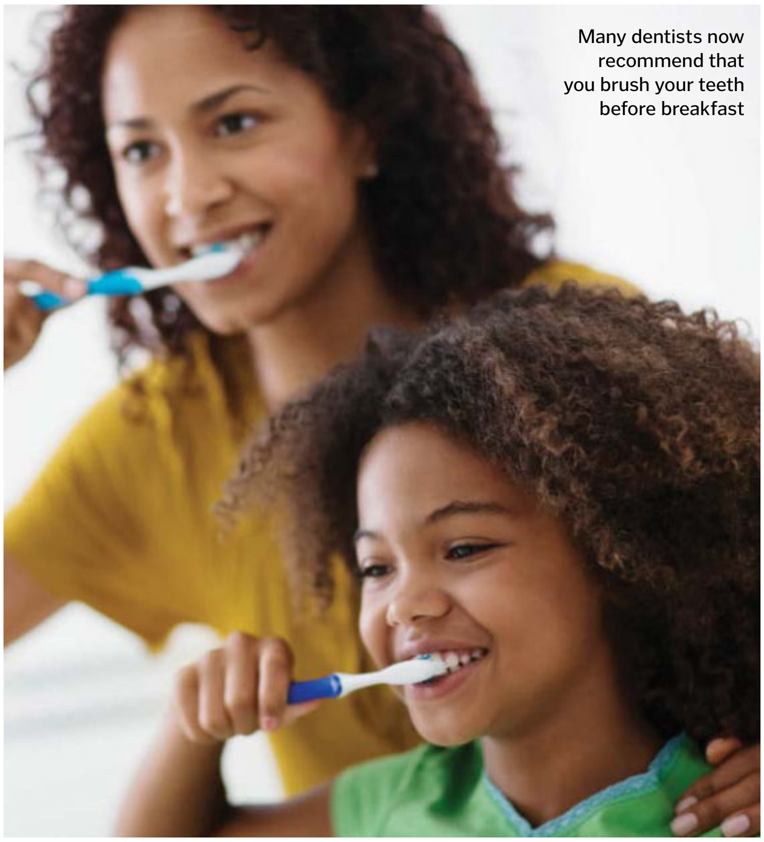
T-Rex versus Dumbo

Dear **HIW,**
Were elephants around at the same time as the dinosaurs?
Thanks,
Shravan Kumar

Hi Shravan, thank you for your question! Elephants weren't around at the same time as the dinosaurs. Modern day elephants can trace their ancestry all the way back to a tiny mouse-sized mammal called Phosphatherium, which somehow survived the huge extinction event that wiped out the dinosaurs roughly 65 million years ago. Scientists believe that even the most primitive of elephant ancestors didn't evolve until around five million years after the dinosaurs went extinct.



T-Rex died out long before elephants walked the Earth



Many dentists now recommend that you brush your teeth before breakfast

The tooth of the matter

Dear **HIW,**
Should we brush our teeth before or after breakfast? Does it impact how healthy our teeth are?
Thanks,
Emilio Rimini

Common sense suggests that brushing your teeth after breakfast is the best option, as this will rid you of any food and debris that could cause damage to your teeth. However, the opposite may in fact be true. If you've had something acidic such as fruit juice, these acids can weaken tooth enamel if you brush within 30 minutes of consuming them. Instead, many dentists now recommend that you brush as soon as you wake up, as this helps to coat the teeth with a layer of protective fluoride, preventing acidic foods from damaging the enamel and dentine.

"Acids weaken tooth enamel if you brush within 30 minutes"

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Nice infographic via **@HowItWorksmag** explaining how a firework works.

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@HowItWorksmag is incredible yet again! The articles about space are truly MIND BOGGLING.

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@HowItWorksmag Wow! Jack Griffiths is amazing in this video, your best presenter yet. He should do all your videos!

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@HowItWorksmag I like your explanation about the differences between viruses and bacteria. As a virologist, viruses fascinate me.

@ProfBrianCox
Just had to reboot my fridge. Is the world getting too complicated?

@neiltyson
When a Doctor's prognosis is bad, we want to seek a second opinion, but when a prognosis is good we're somehow okay with it.

@DarrenBarnard1
@HowItWorksmag a medium sized cumulus cloud weighs about the same as 80 elephants.

@CarletonRutter
Just bought two amazing books from the @HowItWorksmag team. #extremeweather and #aircraft

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